THE FUNDAMENTALS OF LEARNING

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PREFACE

This volume reports investigations covering a period of three years, dealing with the fundamental facts and forces in learning. Except as noted in the text, the writer is responsible for the planning of the experiments, for the inferences drawn from their results, and for the methods of presenting these. But the execution of the work would have been impossible without the expert assistance of Dr. Ella Woodyard and Dr. Irving Lorge. Much of the experimentation reported in Chapter X was done by Miss Mabel Wilcox and Miss Parrish Little (Mrs. Jette).

It was our original purpose to work at certain basic problems until satisfactory solutions were reached; and in general we have done so. But the results suggested certain new problems of such great importance that we have thought it wise to study these also, even without expectation of attaining a final settlement of them. As an indirect consequence of this, one important problem in our original set, that of the relation of the formation of conditional reflexes to associative shifting of the ordinary sort, has been treated only very cursorily.

Edward L. Thorndike

June, 1931

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CHAPTER I

Introduction

We are concerned in this volume with the fundamental facts of learning whereby a situation which first evokes response A later evokes response B, different from A. The main questions which we have asked and tried to answer by adequate experiments are the following:

(1) What happens when the same situation or stimulus or state of affairs acts repeatedly upon an organism which is, except for the action specified and for accidental variations, the same? What does the mere repetition of a situation, in and of itself, do to the mind? More particularly, does the mere frequency of an experience cause useful modifications in the one experiencing it? And do the more frequent among the varying responses to this one situation gain in strength and increase their probability of occurrence in the future, while the less frequent ones weaken?

(2) What happens when the same connection occurs repeatedly in a mind which is, except for the connection specified, the same? What does the mere repetition of a connection, in and of itself, do? In particular, does the occurrence of two mental events in temporal sequence strengthen the tendency of the first of them to evoke the second? Our experiments show that mere sequence, in and of itself, is nearly, or quite, powerless, and that the second term of the sequence must in some sense "belong" to the first, be a sequent *of it* or a response *to it*, if learning is to result. So we ask (2*a*) What does the repetition of a sequence whose two terms "belong" together do? What happens when we repeat again and again a connection in the sense of a situation and some one same response to it?

(3) What effect has the after-effect or consequence of a

connection upon it? What elementary and general facts explain the influence which rewards and punishments have upon the learning of animals and man? In particular, does a satisfying state of affairs which follows or accompanies and "belongs to" a mental connection really strengthen it, or does it only seem to; or is the difference a mistaken observation of what is really a product of frequency or recency or congruity, or freedom from inhibition, or consummatory quality, or something else? Our experiments prove that satisfyingness attached to a connection does strengthen it, and so they lead to a fourth question.

(4) How does the satisfying food or approval or progress toward a desired end add strength to the connection to which it is attached? In particular, is its action direct, or does it operate by causing the animal to review or rehearse the connection? Does its potency take effect then and there when it follows the connection, or later when the animal, on being confronted by the situation again, recalls or imagines that such and such a response to that situation produced such and such a satisfying consequence? Is the action universal, so that any satisfier will strengthen any connection to which it is attached; or may it be specialized, so that certain satisfiers benefit only certain sorts of connections?

(5) How does the unfavorable effect of punishment come about? Is it the opposite or the negative of reward, annoying consequences weakening connections in the same fashion that satisfying consequences strengthen them, or does punishment operate in a different fashion of its own?

Less important problems in the psychology of learning concern (6) the influence of primacy and (7) that of recency, (8) the so-called "law of the resolution of physiological states," that an oft-repeated series tends to lose its intermediate terms, and (9) the polarity or unidirectional quality of mental connections.

The facts found have made ~~clear the~~ importance for learning of two principles: the identifiability of the situa-

tion and the availability of the response; and Chapter XIII is devoted to demonstrating and illustrating these two principles. Chapter XIII includes also a discussion of the principle of readiness, though we have little that is new to contribute in this case. Two other chapters are devoted to mental systems, and to associative shifting with special reference to the phenomena of the conditional reflex.

Among the new techniques used in our experiments on the influence of the repetition of a connection is the presentation of series of two hundred or so pairs occurring from one to forty-eight times, making a total series of one to four thousand pairs. The pairs may be of any sort, and the subject may be set to attend to them in various ways, such as to copy them, or to listen to them, or to try to learn which second member goes with which first member of a pair, or otherwise. This technique offers a new and profitable approach to certain problems concerning the distribution of practice, the influence of intelligibility on memory, the impressiveness of certain stimuli, and other topics. Sample investigations to show its applicability are reported in Chapters V and VI.

One fact observed was of such general importance that we made special experiments to confirm it and others to explain it. This is that the impressiveness of a first member in a pair (say a word-number pair) not only causes that word to be remembered, but also strengthens the connection leading from it. Suppose, for example, that the series contains *kiss 38, devil 47, vomit 19, derive 26, hasten 53,* and *seldom 81*, each pair occurring *n* times. Not only will the subjects remember that the series contained *kiss, devil,* and *vomit* much better than they remember that it contained *derive, hasten,* and *seldom;* they will also remember that *kiss* was followed by *38, devil* by *47*, and *vomit* by *19* much better than that *derive, hasten,* and *seldom* were followed, respectively, by *26, 53,* and *81*. The experiments made to confirm and explain this fact lead to hypotheses which, if further work verifies them, will be of great im-

portance for the theory of learning and the practice of teaching.

The searching and critical analysis to which the concepts of learning, habit, and the association of ideas have recently been subjected, and the positive doctrines which have been advocated, are reviewed in the light of our experimental results. We have not sought to reproduce in full the views of Watson, Carr, Peterson, Woodworth, McDougall, Tolman, Cason, Hollingworth, Hobhouse, Köhler, Koffka, Ogden, Lewin, Gengerelli, Van der Veldt, Warden, and others who have dealt with these problems. But we have tried to include the important facts and criticisms, and to work out and present a reasonable solution so far as is possible from existing knowledge. This solution takes the form of a new associationism, or better, since it differs deeply and widely from that older British associationism, of a new connectionism.

As a test of the adequacy of connectionism, we have searched for the varieties or features of mental life which seem least amenable to explanation by it, and have tried to discover in what respects it is really inconsistent with the facts. One of the hardest facts to reconcile with a psychology that limits itself to connections and readinesses, original and acquired by repetition or reward, is the tendency for a word to evoke its opposite.

We have studied this case of apparent transcendent activity as part of a general study of systems which organize and direct trains of thought. The results, presented in Chapter XIV, justify the connectionist's faith. They also set the phenomena of the free-association experiment in a new light, and should result in substantial improvements in the use of the experiment as an instrument of diagnosis or detection.

Our presentations of all these matters are perhaps unnecessarily burdened with descriptions of the experiments and tables reporting the results. Some of this evidential material has been isolated in appendices; and perhaps more

of it should have been. The critical student will, however, desire to have all of this available, at least for reference; and in general he will prefer to have it along with the general argument and conclusions, rather than in appendices. The reader who cares for conclusions rather than evidence can attain his end by first reading the first ten lectures of Human Learning [Thorndike '31], a popular account of some of this work and kindred matters, and then reading the present volume with the following omissions:

Chapter II. Section 5
IV. Sections 2, 3, and 4
VIII.
IX. From p. 190 to the end
XII.
XIII. Section I
XIV. Table 128
XVIII. Sections 3, 4, 5, and 6
Appendices I, II, III, IV, V, VI, VIII, and IX

CHAPTER II

THE INFLUENCE OF THE REPETITION OF A SITUATION

§ 1. THE PURPOSE OF THE EXPERIMENTS

As is well known, two laws or principles of connection-forming have been proposed. The first, which we may call the law of exercise or use or frequency, asserts that, other things being equal, the oftener a situation connects with or evokes or leads to or is followed by a certain response, the stronger becomes the tendency for it to do so in the future. If, for example, by some means R_2 is somehow made to follow closely upon S_1 a hundred times, the tendency for S_1 to evoke R_2 will become stronger than it was and may become stronger than some other tendency, $S_1 \longrightarrow R_1$, which was originally stronger than it. This law has been generally accepted as a part of orthodox psychology, but it has recently been challenged. The second, which we may call the law of effect, asserts that what happens as an effect or consequence or accompaniment or close sequel to a situation-response, works back upon the connection to strengthen or weaken it. This law has not been so generally accepted; and among those who do accept it in the form stated here, there would be a rather wide variety of opinions concerning just what it is in the effect or sequel of a connection that works back to modify that connection, and what conditions are necessary to enable it to do so.

We shall subject both of these laws to new experimental tests, designed to discover more fully and exactly what use or repetition of a mental connection or bond does to that connection, and what certain sequels of a mental connection do to it. The present chapter does not, however, deal directly with either of these laws, but with the still more

fundamental question of the influence of repetition of a *situation*. If the same situation is presented to a person again and again without any effort to alter or control the connection or connections leading therefrom to a response or responses, what happens? In particular, if a given situation evokes two or more responses with varying frequencies, will repetition of the situation strengthen the stronger tendencies at the expense of the weaker, or will repetition merely maintain the *status quo*? Given a situation or state of affairs S_1 to which (presumably because of minor accompanying circumstances in the animal) there will be, in the first twenty occurrences, varied responses R_1, R_2, R_3, etc., with frequencies of 16, 3, and 1, will the next twenty occurrences tend to show R_1 oftener than 16 times and R_2 and R_3 less often than 3 and 1, or will the relative frequencies remain unchanged? Psychologists, in so far as they have faced this question at all, have usually taken it for granted that the first answer is correct, but no proof of its correctness has ever been given.

The theoretical importance of the question lies in its bearing upon the laws of use and effect and upon certain theories of facilitation and inhibition in the nervous system. If the second answer is correct, the law of use has a very restricted influence, and some law of effect *must* be true in cases where one response is selected for survival from many responses to the same situation. If the first answer is correct, there must be some physiological selection by repetition. It may be a change at the synapses whereby the repeated conduction of a stimulus over the same path actively enriches the tendency so to conduct at the expense of tendencies to conduct elsewhere. Or it may be some sort of selective integration whereby the repeated action of more or less of the associative system as a whole in a certain pattern depresses the tendency for it to act in other patterns. Or it may be something else. But if an animal which responds to S_1 by R_1 90 times and by R_2 10 times, by this mere fact of relative frequency becomes an

animal which responds to S_1 by R_1 91 times and by R_2 9 times, and so on, until it is an animal which responds to S_1 by R_1 100 times and by R_2 zero times, there has been some active influence of the physiological basis of $S_1 \rightarrow R_1$ upon the physiological basis of $S_1 \rightarrow R_2$, increasing the probability of the former occurrence at the expense of the probability of the latter.

If the first answer is false, or if the quantitative amount of influence of relative frequency upon future relative frequency in favor of the more frequent is small, we must be suspicious of "drainage" theories and the like, in general. The case of repetition strengthening the strong at the expense of the weak is a favored case for them.

The importance of the question and answer for the practical control of learning will be only briefly mentioned here. In proportion as repetition *per se* increases the strength of the more frequent connection at the expense of the strength of the less frequent, mere practice may be trusted to produce learning as soon as the desired connection is put at a level of strength above any other one connection, provided that other things (such as intensity, recency, or the effects of the connections) do not act against it in sufficient strength. In proportion as repetition *per se* simply confirms the *status quo*, mere practice will often be fruitless and attention should be given to avoiding practice in error from the outset, and to making the effects of the connections such as will strengthen the desired one and weaken the others. Moreover, great practical importance attaches to this subsidiary question: "If repetition in and of itself does strengthen the stronger connections at the expense of the weaker, what is the amount of its influence?" Our experiments are such that if the first answer is shown to be true they will provide measures of the force of repetition.*

* It should be noted that we are not in this chapter studying the influence of the frequency of occurrences of a *connection*, except in so far as it is a consequence of the frequency of occurrence of a situation. We are here

In experiments to identify and measure the influence of repetition of a situation upon learning, the two desiderata are: (1) that the function or ability used shall be modifiable, and (2) that the consequences of the connections shall be prevented from having any influence, or be so arranged as to have an equal influence upon all the connections. The second is very hard to attain, and few, perhaps not any, of our experiments do attain it fully. Some of them were, in fact, designed to show the competing action of the repetition and the consequences of connections. The limitations, merits, and defects of each experiment may be left for later discussion.

§ 2. Experiments in responding to a length by an estimate of its magnitude

Experiment 1

A set of strips of paper was made, alike in all respects save length, and containing 10 strips 5″ long, 10 strips 5¼″ long, 10 strips 5½″ long, and so on, up to and including strips 11″ long. Each strip had an identification number. These were presented to subject T (the writer) in a random order. T estimated the length of each and entered his estimate after the identification number on a record sheet containing these, saying to himself always as he did so, "Number . . . is . . . inches."* From 100 to 150 judg-

controlling only the situation and letting it evoke such connections, and consequently responses, as it will. In later chapters we shall report experiments upon the influence of the repetition of a connection, in which a situation and some given response to it are presented repeatedly in temporal sequence, with or without a certain relevance or unity or mutual belonging.

* The purpose of this was to equalize the time and attention given to the connection between the identification number and each judgment of its length. However, the identification numbers played approximately a zero part in the case of T in this experiment, so far as he was aware. In only four cases, all late in the series, did the identification number offer any suggestion as to the probable length of the strip. Numbers 105, 205, and 230 came to be thought of as 5″ strips, as they in fact were. Number 16 came to be thought of as probably an 11″ strip. Except for ten or fifteen late judgments of these four strips, all the 2500 judgments seemed to represent connections

ments were made at a sitting. After the entire lot of 250 strips had been so judged, they were shuffled, the record sheet was filed, a new record sheet was taken, and the procedure was repeated. This was done in all ten times, the schedule of dates including twenty sittings scattered irregularly over a period of five days (Dec. 10–14, 1925).

At the beginning of the period T knew that the series had 10 strips of each length and began at 5″ and progressed by ¼″, but he was not sure whether it ended at 11″ or 12″. Not until the second round was well under way did he realize that since there were 250 entries on the record sheet, the series must end at 11″! During the entire period T never measured any of these strips or any other object, and acquired no experiences concerning lengths save that given by these 2500 uncorrected judgments themselves and by the fact that he knew the constitution of the series as just stated.

Any given length, say 7½″, was thus judged 100 times, so that we may tabulate the frequency of the connections as shown in Table 1.

TABLE 1

SAMPLE TABULATION OF RESPONSES FOR ONE LENGTH

Situation	Response	Frequency in Successive Tens									
		1	2	3	4	5	6	7	8	9	10
7½″ strip seen	Saying 61*				1				1		
7½″ strip seen	Saying 62							1			
7½″ strip seen	Saying 63										
7½″ strip seen	Saying 7	1			5		1				
7½″ strip seen	Saying 71	2	2	1	1	3	4	4		1	1
7½″ strip seen	Saying 72	1	5	5	1	4	5	5	6	7	3
7½″ strip seen	Saying 73	5	3	4	2	3			3	2	6
7½″ strip seen	Saying 8	1									

* The verbal and written form 61 was used for 6¼, 62 was used for 6½, 63 was used for 6¾, etc.

Such tabulations have been made for each length and studied in many ways to discover to what extent the response which has the greater relative frequency at the be-

from the length of the strip to the estimate. This was true also of all the other experiments in judging lengths, to be reported later.

ginning, increases its frequency at the expense of responses of less frequency. Whatever the way taken to measure the waxing of the more frequent and the waning of the less frequent, the result is a negative. For example, consider Table 2 which gives the frequencies for successive thirties, omitting the first ten. Table 2 also includes the results for thirty repetitions at a date two weeks later (Dec. 31, 1925, and Jan. 2, 1926). The response which is the most frequent in trials 11 to 40 gains in trials 71 to 100 in seven cases, remains the same in three, and loses in fifteen. On the other hand, the connections involved in estimating these lengths do not seem to remain in *status quo*, but rather to change notably. Nor are these changes haphazard. For example, there is an increase from trials 11–40 to trials 71–100 in the use of 5 and 11 as estimates from 94 to 120 times, and there is a tendency to estimate the lines as longer in trials 71–100 than in trials 11–40. In the series of trials 101–130, done two weeks later, 5 and 11 are used 119 times; the lines are estimated very much shorter than they were in trials 71–100, and shorter than they were in trials 11–40 or in trials 41–70.

Experiments 2, 3, and 4, reported in Appendix I, were of the same general plan as Experiment 1. Their results show (1) that the tendencies to respond to a length to be judged constitute a susceptible, variable condition, (2) that with continued repetition of the situation this condition becomes less variable, tending toward stereotypism, but (3) that the more frequent tendencies do not gain at the expense of the less frequent.

§ 3. Experiments in responding to a signal by making a movement

Experiment 5

Subject T (the writer), with eyes closed, drew a line to be as nearly as possible 2″ long, then one to be 4″ long, then one to be 6″ long, then one to be 8″ long. This series of

Table 2

Distribution of responses of T to lengths 5″ to 11″, in successive 30's

Sit.	Res.	Frequencies in 11 to 40	41 to 70	71 to 100	101 to 130	11 to 70	71 to 130
5	5	27	29	29	30	56	59
	51	3	1	1	0	4	1
51	5	17	23	26	28	40	54
	51	12	7	4	2	19	6
	52	1				1	
52	5	2	2		16	4	16
	51	14	17	10	14	31	24
	52	12	11	16		23	16
	53	2		4		2	4
53	5				4		4
	51		5	1	16	5	17
	52	21	15	17	10	36	27
	53	9	10	11		19	11
	6			1			1
6	51				4		4
	52	5	2	1	22	7	23
	53	15	22	11	4	37	15
	6	10	6	13		16	13
	61			3			3
	62			2			2
61	51				1		1
	52				3		3
	53	11	6		19	17	19
	6	13	19	13	6	32	19
	61	6	5	15	1	11	16
	62			2			2
62	52				2		2
	53	1		1	10	1	11
	6	3	4		13	7	13
	61	11	19	6	5	30	11
	62	10	6	19		16	19
	63	3	1	4		4	4
	7	2				2	
63	6	2	1		7	3	7
	61	4	5		17	9	17
	62	13	17	9	6	30	15
	63	6	7	14		13	14
	7	4		7		4	7
	71						
	72	1				1	
7	6				1		1
	61	1			6	1	6
	62	2	8	3	14	10	17
	63	11	16	10	9	27	19
	7	10	5	10		15	10
	71	5		6		5	6
	72	1		1		1	1
	73		1			1	
71	61				1		1
	62	2			6	2	6
	63	3	5		17	8	17
	7	7	14	8	4	21	12
	71	9	8	8	1	17	9
	72	6	3	11	1	9	12
	73	3		3		3	3
72	61	1		1		1	1
	62		1			1	
	63	5			7	5	7
	7	4	1		12	5	12
	71	11	11	2	7	22	9
	72	9	14	16	1	23	17
	73		3	11	3	3	14
73	63				1		1
	7	1			4	1	4
	71	1			16	1	16
	72	15	4		9	19	9
	73	11	16	6		27	6
	8	1	10	17		11	17
	81	1		7		1	7

TABLE 2 (*Continued*)

Sit.	Res.	Frequencies in 11 to 40	41 to 70	71 to 100	101 to 130	11 to 70	71 to 130
8	63		1			1	
	7		1			1	
	71				4		4
	72	7	4	1	13	11	14
	73	9	18	11	12	27	23
	8	8	6	18		14	18
	81	4				4	
	82	2			1	2	1
81	71				1		1
	72		1	1	10	1	11
	73	5	12	1	16	17	17
	8	15	14	12	3	29	15
	81	4	3	8		7	8
	82	3		3		3	3
	83	2		5		2	5
	9						
	91	1				1	
82	72				2		2
	73	2	1	1	14	3	15
	8	7	12	4	10	19	14
	81	8	11	13	3	19	16
	82	10	5	6	1	15	7
	83	1	1	6		2	6
	9						
	91	1				1	
	92	1				1	
83	73		1		3	1	3
	8	1	6		18	7	18
	81	8	9	2	3	17	5
	82	8	7	8	3	15	11
	83	6	5	6	2	11	8
	9	4	2	10	1	6	11
	91	2		3		2	3
	92	1		1		1	1
	73				1		1
	8	1	1		2	2	2
	81		1		6	1	6
	82	5	8	1	10	13	11
	83	13	7	6	5	20	11
	9	4	8	5	1	12	6
	91	2	2	6	2	4	8
	92	2	2	7	3	4	10
	93	2	1	4		3	4
	10	1		1		1	1

Sit.	Res.	Frequencies in 11 to 40	41 to 70	71 to 100	101 to 130	11 to 70	71 to 130
91	81				2		2
	82		2		9	2	9
	83	4	7		3	11	3
	9	7	6	1	2	13	3
	91	7	5	1	4	12	5
	92	6	5	7	8	11	15
	93	4	3	12	2	7	14
	10	2	2	9		4	9
92	82	1				1	
	83				2		2
	9	2	2		6	4	6
	91	1	4		3	5	3
	92	6	5		7	11	7
	93	8	11	4	12	19	16
	10	8	6	9		14	9
	101	4	2	17		6	17
93	92	1	3		5	4	5
	93	2	4		10	6	10
	10	10	12	3	14	22	17
	101	11	11	17	1	22	18
	102	5		10		5	10
	103	1				1	
10	92		1			1	
	93		2			2	
	10	3	6		6	9	6
	101	16	12	3	23	28	26
	102	10	8	24	1	18	25
	103	1	1	3		2	3
101	91		1			1	
	92	2	1			3	
	93	1				1	
	10		2	1		2	1
	101		5	3	14	5	17
	102	20	18	10	14	38	24
	103	7	2	15	2	9	17
	11		1	1		1	1

TABLE 2 (*Continued*)

Sit.	Res.	Frequencies in					
		11 to 40	41 to 70	71 to 100	101 to 130	11 to 70	71 to 130
102	101	1	1			2	
	102	5	7	1	14	12	15
	103	15	19	18	14	34	32
	11	8	3	11	2	11	13
	111	1			1		
103	102		2		2	2	2
	103	11	15	7	9	26	16
	11	19	13	23	19	32	42
11	101	1				1	
	102						
	103	1	4		2	5	2
	11	25	26	30	28	51	58
	111						
	112	1				1	
	113	2				2	

four acts he repeated 950 times. He saw no line of 3800 until all had been drawn, nor did he have any experience in drawing any other lines during the experiment. Each line was drawn quickly as one dash, and no correction was made even when T thought that the result was far too short or too long. T tried throughout to make each line as a single unitary movement due to a single impulsion connected with the idea of *Draw 2 inches* or *Draw 4 inches* or *Draw 6 inches* or *Draw 8 inches*, as the case might be. As the experiment progressed the movements seemed to him to be somewhat less spasmodic and less determined by an original jerk of the hand and more determined by the sensation from the pencil on the paper. He was tempted to make the movement more slowly so as to be able to stop it when it seemed to be going too far and to extend it when it seemed to be short; but withstood this temptation completely so far as he is aware. He changed somewhat from a tendency to push his hand with a certain initial force to a tendency to push the pencil to hit a spot 2″ (or 4″ or 6″ or 8″ as the case might be) to the right. The second type of movement was, to the best of his knowledge, no slower on the whole. Thirty or 60 lines of each length were drawn at a sitting; from one to four sittings were held daily.

The technical arrangements were very crude. T drew the lines always with the same sort of pencil sharpened to

about the same bluntness on the same kind of paper (ordinary letter size) held on a large pad, with the longer edge parallel to the direction in which the lines were drawn. He drew 3 sets of 4 lines each on a sheet; then with eyes still closed, put it face down on a pile, opened his eyes, placed another sheet on the pad, shut his eyes and repeated. After he drew the four lines, he pulled the paper up on the pad so that the position of the arm and hand would be approximately the same for the next four lines. In spite of their crudeness, these arrangements were fairly satisfactory, perhaps more so than a rigorous but artificial control would have been. The variations in conditions may have existed in respect of single drawings, but for one hundred compared with another hundred these disturbances are probably equalized.

The important desiderata were to have conditions on the average alike in successive hundreds, and to have the subject deprived of any knowledge of how long the lines which he drew were. The first seems to have been obtained, at least approximately. The second surely was. T had no awareness of any changes either progressive or abrupt save those noted above.

He had no idea during or at the close of the experiment that his lines were too short, that they had become longer as the experiment progressed, or that they varied as much as they did. There was a very great increase in the length of the lines in the later fifties over the length for the first fifty in the case of all four lengths, but he was utterly unaware of this. There was a notable decrease in the length of the last hundred of each length as compared with the previous hundred, but he was utterly unaware of this also. Nor was he any more aware of the more gradual changes elsewhere.

The lines were measured to .1 inch (in a straight line from start to finish). 20 means from 2.0 inches up to 2.1 inches, 21 means from 2.1 inches up to 2.2 inches, etc.

The responses to the situations, *"Draw a 2″ line,"*

"Draw a 4" line," "Draw a 6" line," and *"Draw an 8" line"* were tabulated by successive fifties and studied. They were then combined into nine hundreds and one fifty. In this form they are presented here, as Table 13.

The response which was most frequent in the first hundred does not gain at the expense of the less frequent responses. This is true by any reasonable method of choosing the most frequent response. The method which we have used is to take that sequence of lengths (1) which has a total frequency greater than any other sequence and (2) which has a sum of frequencies nearest to 25, and (3) which includes, or is close to, the median length. If

TABLE 13

THE RESPONSES OF T IN DRAWING 950 SETS OF LINES, EACH SET COMPRISING FOUR RESPONSES, ALL BEING WITHOUT KNOWLEDGE OF RESULTS

2 inch lines

Response	Frequency 1 to 100	101 to 200	201 to 300	301 to 400	401 to 500	501 to 600	601 to 700	701 to 750	751 to 850	851 to 950
9	2									
1.0	5									
1.1	10									
1 2	9	1		1	1					
1 3	10	8	4	1	2		1			
1.4	6	9	6	2	2	1	3			1
1.5	15	12	11	5	6	1	5	1	1	1
1 6	11	19	15	11	13	8	7	3	2	6
1.7	6	17	26	13	12	15	12	6	4	9
1.8	14	9	9	21	19	12	26	4	11	23
1.9	4	9	14	18	10	14	13	5	17	17
2.0	3	5	8	8	18	13	12	6	16	18
2 1	3	6	4	8	3	12	6	9	19	13
2.2	1	3	3	9	5	12	9	7	11	10
2 3		1		3	7	5	2	6	8	
2.4		1			1	1	2	1	4	1
2 5	1				1	6	1	2	4	1
2.6									2	
2.7							1		1	
Median	1.55	1.71	1.75	1.88	1.87	1.99	1.88	2.10*	2.09	1.96
Q	.26	.17	.15	.15	.17	.20	.15	.19	.15	.13

4 inch lines

Response	Frequency 1 to 100	101 to 200	201 to 300	301 to 400	401 to 500	501 to 600	601 to 700	701 to 750	751 to 850	851 to 950
1.6	1									
1.7										
1.8	2	1								
1.9	11		1	1	1					
2.0	6	1	1							
2.1	9	3	3	1						
2.2	17	10	5		2				1	
2.3	6	8	4	1	2		3	1		
2.4	13	12	6	5	4		1			
2.5	6	18	15	10	5	2	8	2		2
2.6	9	6	11	12	9	3	7		2	2
2.7	4	8	14	15	8	3	13		1	7
2 8	8	7	14	9	8	15	12	6	2	13
2.9	5	7	8	14	12	6	8	4	3	12
3.0		5	11	14	12	9	10	3	6	15
3.1	2	1	4	8	13	8	6	4	14	13
3.2		4	3	8	7	12	7	4	12	7
3.3	1	7			4	7	5	6	17	10
3.4		1		1	2	5	4	9	16	10
3.5		1		1	3	12	7	7	9	3
3.6					5	3	3	1	7	1
3.7					2	9	3	1	7	3
3.8						3	1		1	2
3.9						3	2	1	2	
4.0					1					
4.1								1		
Median	2.35	2.58	2.73	2.85	2.99	3.23	2.98	3.32*	3.35	3.09
Q	.24	.25	.19	.20	.23	.31	.28	.25	.17	.22

* Determination made from 50 responses.

TABLE 13 (*Continued*)

6 inch lines

Response	Frequency 1 to 100	101 to 200	201 to 300	301 to 400	401 to 500	501 to 600	601 to 700	701 to 750	751 to 850	851 to 950
2 5	2									
2.6	3									
2 7	6		1							
2 8	3		1							
2.9	10	3	1		1					
3.0	6	2	1	1	1					
3 1	6		3	2					1	
3.2	10	4	2	2	1		2			
3.3	7	8	7	2	1		4			
3.4	8	8	8	1	1	1	5		1	2
3.5	7	7	13	9	6	1	6			
3.6	5	11	12	7	7	2	7	3		3
3 7	6	10	8	9	5	7	5	1		3
3.8	6	11	8	14	9	2	6	3	1	7
3 9	3	8	12	7	8	4	4	2	3	12
4.0	2	5	5	14	2	7	10	3	4	10
4.1	4	5	10	10	11	9	9	4	8	15
4.2	4	5	2	12	12	10	6	5	11	18
4.3	1	6	3	3	10	9	4	8	11	5
4.4		2	1	3	5	7	4	3	12	6
4.5			2	2	7	10	4	4	9	5
4.6		1		1	4	8	6	4	9	6
4.7	1	1		1	4	5	6	3	8	4
4.8		1			2	5	6	3	7	1
4.9		1			2	2	3	1	8	3
5.0					1	4	1		4	
5.1		1				2	1	1	2	
5.2						2	1	1		
5.3						1		1		
5.4						2			1	
Median	3.36	3.77	3.71	3.94	4.17	4.38	4.11	4.35*	4.48	4.19
Q	.36	.28	.24	.23	.29	.28	.43	.26	.25	.21

8 inch lines

Response	Frequency 1 to 100	101 to 200	201 to 300	301 to 400	401 to 500	501 to 600	601 to 700	701 to 750	751 to 850	851 to 950
3.3	1									
3 4										
3 5	1									
3.6	2									
3 7	3									
3 8	2									
3 9	7	2								
4.0	5	1								
4.1	7	2	1	1						
4.2	5	5	2	1						
4.3	7	3	1	1	1					
4.4	7	2	1	1	1					
4.5	10	2	7	2					1	
4.6	5	4	9	1						
4.7	9	7	13	4	1					
4.8	4	7	8	6	1		3		1	
4.9	1	9	8	3		1	2	2	1	
5.0	2	7	7	11	5	1	7	1		2
5 1	6	5	7	7	3	2	2	1		1
5.2	4	7	9	5	6	2	6	5		5
5.3	5	5	5	7	6	6	4	1	4	5
5.4	1	8	5	8	11	2	6	3	6	5
5.5	1	3	4	11	10	8	5	3	2	8
5 6	2	4	3	10	12	6	7	2	7	10
5.7	2	3	2	5	9	11	4	2	8	10
5 8	1	5	3	7	5	7	9	6	8	12
5.9		7	1	3	8	6	5	6	9	8
6 0			3	2	6	7	3	2	11	6
6 1		1	1	3	4	4	3	1	9	9
6 2					4	8	7		8	6
6.3					3	5	6	1	8	5
6.4		1			2	7	2	2	8	3
6 5					1	2	8	2	5	1
6.6						2	4	3	1	
6.7					1	1	3	3	2	1
6.8						2	3	1		1
6.9						4	1	2		2
7.0						2			1	
7.1						3		1		
7.2						1				
Median	4.53	5.09	5.00	5.40	5.64	5.97	5.84	5.88*	6.03	5.83
Q	.37	.37	.30	.31	.27	.37	.46	.50	.28	.27

* See footnote on page 16.

the first and third of these criteria conflict, we make a reasonable choice, usually favoring the third. For 2″ lines all three agree on 1.5 and 1.6. For 4″ lines we use 2.2 and 2.3. For 6″ lines all three agree on 3.2, 3.3, and 3.4. For 8″ lines we use 4.4, 4.5, and 4.6.

The *status quo* is not maintained. On the contrary, there

are shifts of mean tendency and changes in variability. The shifts of the mean tendency are in general toward longer lengths and toward the correct lengths. The variable error is in general reduced.

The results of Experiments 6 to 22, which are all of the same general pattern as Experiment 5, are reported in Appendix II. They show that the situation represented by a signal or a command makes widely varying connections, with notable shifts of the central tendency and changes in the variation around it, but that the shifts are not by waxing of the initially most frequent connection at the expense of the initially less frequent. They do not give any support to the doctrine that the response which an animal makes oftenest to a maze alley or a puzzle box or a multiple-choice apparatus will thereby gain one iota in probability of future response.

§ 4. The nature and measurement of strength of connection

So far, we have used the terms situation, response, and connection without dependence upon any rigorous definitions of them. What we have found and stated will be equally true and useful by any reasonable definitions. And the terms situation and response may continue as crude but convenient names for some state of affairs without or within the organism and some sequent act or condition of the organism, which is, or seems to be, determined in part by said state of affairs.* The meaning which we attach

* Element of a situation and feature of a response would be more exact names for what we mean by situation and response. Any situation, such as we use in our experiments, or teach children to respond to in school, or deal with in any of the mental sciences, is, of course, always a part of a total situation, and is always responded to by a person whose mind has a set characteristic of that moment and perhaps of no other. Any response that science deals with is similarly always a part of a total behavior of the animal. We abstract from some total state of nature when we say that a child responds to the situation "How much is 7 + 4 + 2?" by the response "Writing 13," as chemists abstract from the total state of nature when they say that oxygen and hydrogen unite to form water.

to the term "connection" may profitably be stated. That a connection $S_1 \rightarrow R_1$ exists in a certain organism means in this study simply that there is a probability greater than an infinitesimal that, if S_1 occurs, R_1 will occur. In practice, very low probabilities, say of less than .00001, will not be called connections.

So far, we have argued only concerning the number or percentage of occurrences of a certain connection, such as that between seeing a strip 5¾″ long and estimating it as 6″, or between thinking "Draw a line 4″ long" and drawing a line 3.2″ long. The percentage which the number of occurrences of a connection, $S_1 \rightarrow R_1$, is of the total number of connections made with S_1, (i.e., $S_1 \rightarrow R_1$, $S_1 \rightarrow R_2$, $S_1 \rightarrow R_3$, ... $S_1 \rightarrow R_n$), is obviously closely related to the strength of the connection $S_1 \rightarrow R_1$, by any reasonable definition of "strength of a connection"; and the facts which we have so far presented concern the strength of connections and the influence of repetition of a situation upon the relative strength of the connections leading from it by any reasonable definition of strength. It seems best, however, to adopt a provisional definition of "strength of a connection" so that we may, in the experiments next to be described, consider the question of the strengthening of the stronger connections leading from S_1 at the expense of the weak connections leading from S_1, as well as the question of the increase of the more frequent responses to S_1 at the expense of the less frequent.

The most generally accepted and acceptable meaning for the strength of a connection with S_1, say of $S_1 \rightarrow R_1$, is the probability that R_1 will occur if S_1 occurs. This probability, of course, ranges from 0 to 1. Among the connections with a probability of 1 at any given time and for the ordinary conditions of the person in question and for the ordinary occurrence of S_1—that is, among those connections which are sure to occur whenever S_1 occurs to-day to the person awake and attentive—there are, obviously, varying degrees of strength. Some of these connections would

still operate and some would not if S_1 occurred when the person was very sleepy, or plus distracting accompaniments, or after an interval of a year with no practice. We can differentiate among these connections with a probability of 1 at the present under ordinary conditions, by measuring their probabilities (*a*) at some future time, or (*b*) after disuse, or (*c*) with stronger competition.

It is not certain that probability of occurrence now against ordinary competition is the same as (that is, is perfectly correlated with) probability of occurrence now when the subject is asleep, or of occurrence after one hundred days of disuse, or of occurrence in excitement. Indeed, it seems almost certain that some of these correlations are not perfect. In general, caution is desirable in arguing beyond the time being, or to extraordinary conditions of the organism.

We can differentiate among these by the time required for relearning to some defined degree of strength. Connections which do not act to produce responses of any appreciable frequency, that is, which show 0 occurrences, may be of widely different strength. The reader may, supposing him to have studied Latin in the past, not respond by the correct English equivalents of any of these Latin words: *dedi, stare, utor, exegi, frumentum.* The frequency may be 0 for every one of them; but the connections involved may be relearned in vastly different amounts of training.

In the present series of experiments and arguments we shall not need to argue concerning anything beyond the time span of a few days or different from ordinary mental conditions. Nor shall we have to differentiate among probabilities of 1.00 or of only infinitesimal amount. For all the probabilities with which we shall deal will be less than 1 and clearly above zero. We are concerned with cases where $S_1 \longrightarrow R_1$, $S_1 \longrightarrow R_2$, $S_1 \longrightarrow R_3$, etc., all have probabilities with values above the infinitesimal and below 1.

Our difficulties are factual and statistical within this sim-

ple scheme. The factual difficulty is that we cannot determine the initial strength of the connections leading from S_1 at all exactly without repeating S_1 many times. What, for example, shall we set as the initial strength of the connections with the situation *Draw an angle of 45°* under the general conditions of Experiment 22, leading to the responses of producing an angle of 0° to .99°, 1° to 1.99°, 2° to 2.99°, and so on, in Br?* If we use the first 333 occurrences of S_1, responses producing angles of 40° or over have 0 strength, and responses of 18° to 23.99° have a strength of $\frac{158}{333}$. But a few days later, responses producing angles of 40° or over have a strength of $\frac{237}{280}$, while responses from 18° to 23.99° have 0 strength.

In the case of many of Experiments 1 to 22, we cannot argue in a straightforward way from the observed frequency of occurrences to the strength of connections, because of the instability of the connections. To obtain such an inventory of T's tendencies in drawing 3″ lines or 4″ lines that the future would, except for changes wrought by repetition, repeat the past, might well require ten thousand occurrences of S_1!

If our initial sampling represents a random picking from a stable *status quo*, we still have a statistical difficulty. Suppose, for example, that the true status is as follows:

$S_1 \rightarrow R_1$	P = .0300
R_2	.0700
R_3	.1000
R_4	.1400
R_5	.1600
R_6	.1600
R_7	.1400
R_8	.1000
R_9	.0700
R_{10}	.0300

* See Appendix II for the details of this experiment.

If we draw at random 100 occurrences of S_1 we shall not have exactly 3, 7, 10, 14, 16, 16, 14, 10, 7, and 3 occurrences of R_1, R_2, R_3, etc. The frequencies of R_5 and R_6 will not always be equal, nor will either always be greater than the frequency of R_4. The connection observed to be of greatest frequency may not be the connection of greatest real strength. In some of the experiments soon to be described, it is desirable to work with total initial frequencies of only 8 or 10 in 100. The effect of the chance error of sampling may then be large in comparison with small differences in real strength, such as the differences between .300, .200, .100, and .050. There are means of allowing for its influence which we shall be careful to take.

Our definition of strength seems at first sight to accord ill with one very common case of strength, that where a person makes a certain response, say 70 times out of 100 and "does nothing" 30 times out of 100.

In such a case there seem to be no connections with a strength of .30 to fill out the probability. And in a sense there are not. Any one of so many thousands of things may occur, no one of which has any appreciable connection with S_1, that we may reasonably think of S_1 in these 30 cases of a hundred as leading on to nothing, the future mental action being determined by other factors than S_1. In a stricter sense, however, there are connections. The person really does something in response to S_1 each time of the hundred that it occurs, but what he does in the 30 cases is negative in its practical consequences (as when he thinks "I don't know that"), or is something which might fit any other situation as well as it fits S_1 (as when he turns back to the course of life which S_1 had interrupted), or is both negative and not specific to S_1.

When the 30 percent of connections leading from S_1 are such that we do not care *what* they are beyond the fact that they are *not* R_1 or R_2 or R_3, etc., it is common to think of them as blanks, failures of response. Our definition and measurement of strength will fit such a case conveniently

enough, if we think of the .70 as the strength of $S_1 \longrightarrow R_1$, and of the .30 as the strength of $S_1 \longrightarrow$ not R_1, and of "not R_1" as made up of a large number of responses each of infinitesimal strength. The response "I don't know" or "I can't" is, by this view, taken to mean that if I were forced to give an answer, I would be as likely to give any one of ten thousand or more answers as any other of them. The response of inattention or turning away, is, by this view, interpreted as a turning to any one of thousands of other things, no one of which has more than an infinitesimal probability of being turned to from S_1.

We are now in a position to distinguish clearly between the alleged potency of great use to draw strength away from the little used connections, for which we have found little or no evidence and against which we shall find evidence later, and the genuine, authenticated potency of use. Repetition undoubtedly does strengthen connections. Indeed, common observation teaches us that repetition strengthens even those connections whose effects are not satisfying, as when a given name or place or face evokes ideas which irritate and pain us.

Case I. Consider the following typical case. A situation, S_1, for example, "What does the word *levirate* mean?" has a connection with the correct meaning (call this R_1), of infinitesimal strength and thousands of connections with "not R_1," each of infinitestimal strength.

We say "infinitesimal" rather than "zero" because any situation to which an animal is sensitive does probably have some infinitesimal tendency to evoke almost every response of which the animal is capable. We shall use $0+$ as the symbol for the amount of strength of such a connection.

The connections from S_1 are then, at the beginning:

$$
\begin{array}{l}
S_1 \rightarrow R_1 \text{ strength of } 0+ \\
S_1 \rightarrow R_2 \text{ strength of } 0+ \\
S_1 \rightarrow R_3 \text{ strength of } 0+ \\
\vdots \quad\;\; \vdots \\
S_1 \rightarrow R_\infty \text{ strength of } 0+
\end{array}
$$

The subject reads, or is told, "*levirate* means the custom of requiring a man to marry his brother's widow." This experience ($S_1 \longrightarrow R_1$) changes the status to:

$S_1 \rightarrow R_1$ strength of 1.0
$S_1 \rightarrow R_2$ strength of 0+
$\vdots$
$S_1 \rightarrow R_\infty$ strength of 0+

$S_1 \longrightarrow R_1$ has been given enormous strength relative to $S_1 \longrightarrow R_2$, etc., for the time being. Repetitions of the experience, or recalls of the $S_1 \longrightarrow R_1$ from within, add to its strength for the future or for action against stronger competition.* We may think of this Case I as the case of addition of strength to a connection of 0 + strength, against the 0 + competition of many other connections, also of 0 + strength.

Case II. The addition of strength to 0 + against appreciable competition. Suppose that the original status is:

$S_1 \rightarrow R_1$, with a strength of 1.0 due to 10 repetitions, one a day for 10 days.
$S_1 \rightarrow R_2$, with a strength of 0+
$S_1 \rightarrow R_3$, with a strength of 0+
$\vdots$
$S_1 \rightarrow R_\infty$, with a strength of 0+

Suppose that the person experiences $S_1 \longrightarrow R_2$ (with an acceptability equal to that of the $S_1 \longrightarrow R_1$ experiences) once a day for 20 days. Just what will then happen when S_1 occurs the thirty-first time, *n* days later, cannot be predicted surely. It will depend on the exact natures of R_1 and R_2 and the total sets in which they occurred. But there will remain, in the long run, other things being equal, an

* It should be noted that in all, or nearly all, cases experiences which so change status by increasing the strength of a connection are endowed with a certain acceptability. They are not rejected or opposed by the animal, but are allowed to live and play their parts. What happens when such an $S_1 \longrightarrow R_1$ is accompanied by repulsion or pain, is a matter for separate consideration.

appreciable strength of $S_1 \longrightarrow R_1$ and an appreciable and greater strength (due to greater frequency and a shorter period of disuse) of $S_1 \longrightarrow R_2$. The status will be approximately:

$$\begin{array}{lll}
S_1 \rightarrow R_1, & \text{with a strength of} & .3 \pm x \\
S_1 \rightarrow R_2, & \text{with a strength of} & .7 \pm y \\
S_1 \rightarrow R_3, & \text{with a strength of} & 0+ \\
\vdots & \vdots & \vdots \\
S_1 \rightarrow R_\infty, & \text{with a strength of} & 0+
\end{array}$$

The subject will be much more likely to respond to S_1 by R_1 or R_2 than by R_3 or R_4 or R_5, etc. He will relearn either of them more readily than he will learn the connections from S_1 to R_3 or R_4 or R_5, etc. He will be more likely to respond by R_2 than by R_1,* and will relearn it more easily.

Case III. The addition of strength to one of several competing connections, each of appreciable strength. Let the status be:

$$\begin{array}{lll}
S_1 \rightarrow R_1, & \text{with a strength of} & .1 \\
S_1 \rightarrow R_2, & \text{with a strength of} & .2 \\
S_1 \rightarrow R_3, & \text{with a strength of} & .7 \\
S_1 \rightarrow R_4, & \text{with a strength of} & 0+ \\
S_1 \rightarrow R_5, & \text{with a strength of} & 0+ \\
\vdots & \vdots & \vdots \\
S_1 \rightarrow R_\infty, & \text{with a strength of} & 0+
\end{array}$$

Suppose that the person is led to experience $S_1 \longrightarrow R_2$ 20 times. Just what the result will be will depend upon several things, including especially the number of the past experiences which have produced the status just described; but, in the long run, other things being equal, $S_1 \longrightarrow R_2$ will gain in strength relative to $S_1 \longrightarrow R_1$, $S_1 \longrightarrow R_3$, $S_1 \longrightarrow R_4$, etc.

There are other instructive cases which might be discussed, but these three are sufficient to introduce and il-

* If the influence of primacy were very strong, this might not be true, but we shall show elsewhere that the influence of primacy is zero or very weak.

lustrate the important facts which characterize all cases where mere repetition of a connection does add to the relative strength of a connection, as contrasted with the cases such as Experiments 1 to 22 (and also Experiments 23 to 27) describe, where mere repetition of a situation leaves the relative strength of the connections leading from it unchanged. It is that the repetition in the former cases is of the situation and one particular prescribed response, whereas in our experiments it is a repetition of the situation and whatever it may evoke. Consequently, the repetition in the former cases adds a positive amount of frequency to one connection and zero to all others.

§ 5. Experiments in connecting numbers with words, spellings with sounds, and words with parts of words

In the experiments in drawing lines and angles with eyes closed,* the situations were definite and manageable. The subject could produce them fully and accurately at will. He had no difficulty in assuming the position, taking the pencil, etc., and thinking "Draw a 2″ line." The responses, selection from which for connection with the situation constituted the learning, were on the contrary ill-defined, elusive, and not capable of being summoned at will. The connection of any particular movement with the situation is made difficult by the difficulty of gaining such control over that movement that it is available when sought and recognizable when made.

In the experiments in judging lengths,† the final responses were definite and manageable. The external situations also could be summoned at will, but the internal consequences of, say, looking at a 9″ strip, were obscure, elusive, and not subject to easy control. The nature and number of the fixations as the eyes moved along the strip, the process of summating their contributions, and whatever

* Experiments 5–22, in § 4 of this chapter and in Appendix II.

† Experiments 1–4, in § 2 of this chapter and in Appendix I.

else goes to make the internal awareness of the strip on its background, cannot be catalogued like a series of phrases, recognized, chosen, and used at will. The connection of any particular measure of length with the external situation of a 9″ strip on its background, is made difficult by differentiation occurring in the internal situation to which the estimate, ". . . . inches," is connected as the final response.

In the remaining experiments, we have freed the process of connection-forming from these difficulties of imperfect identification and control of one of the things to be connected. We have used situations and responses both of which, in the case of the subjects in question, were easily identifiable and available, so that any one of the connections in question could be easily isolated and controlled, and raised to any desired degree of strength.

Experiment 23

In Experiment 23, the situation was a word heard, the response was the writing of a digit from 0 to 9. 150 words were read to the subjects, each followed by a number from 1 to 9. A series of 960 words was then read, at the rate of one every 2½ seconds, and the subjects were required to write a number from 1 to 9 on hearing each word. If they remembered what number had followed the word in the reading of 150, they were to write that. If not, they were to write any number they thought of. Among the 960 words were 50 scattered repetitions of *and*, 50 of *are*, 40 of *in*, 40 of *is*, 60 of *the*, 39 of *be*, 40 of *of*, and 30 of *but*. Various other words were repeated 10 times each, or 4 times each, or 2 times each; but all that concerns us is the history of the responses to the eight words noted.

This experiment has many faults and more valuable experiments of the same general nature will be reported later. But it has certain merits which justify careful consideration of its results. The chief merit is that, since both the situation and the responses were perfectly identifiable and

available at the subject's call, the unimprovable limit is known to be at 100 percent frequency of the word-number connection in question, whatever it may be, and is alike for all human beings of sufficient intellect. We do not need learning experiments to prove that any of the subjects could learn to respond to "*and*, which digit from 1 to 9?" by "7" a hundred times out of a hundred.

Another merit is that the number of possible responses is limited and the same for all subjects. A third is that the inner or mental or cerebral responses and the outer product produced are in strict correspondence. In drawing lines a series of the same inner responses might conceivably result in drawing longer and longer lines if the same nervous discharge produced more vigorous muscular contractions. But in Experiment 23 no such causation of shifts is possible; any change in the numbers written means (except for rare lapses) a corresponding change in the connection.

Some of the subjects could not (or at least did not) think of numbers regularly within the time limit, so that their records were incomplete and were not used. There were 11 such subjects. Some others, 8 in all, missed only an entry here or there, but failed to follow the instructions as to the placing of the entries exactly, so that their records were ambiguous in part and were not used. For 94 individuals we have complete records of the 960 digits written in response to the 960 words read. From each such record we abstract the history of the responses to *and, are, in, is, the, be, of*, and *but*, obtaining 94 tables like Table 38.

From these tables we can measure the extent to which the responses which are the most frequent in the first ten or first twenty appearances of the situation gain in later appearances at the expense of the less frequent. Thus Table 39 compares the records in the later tens of certain responses to *and* and *are*, as follows:

a. Responses occurring once in the first 10.
b. Responses occurring 2 times in the first 10.

c. Responses occurring 3 times in the first 10.
d. Responses occurring 4 times in the first 10.
e. Responses occurring 5 times in the first 10.
f. Responses occurring 6 times in the first 10.

It contains similar facts for the responses to *the*, and to *in*, *is*, and *of*.

Thus the upper left-hand block of the first page of Table 39 relates that there were 494 cases in which some number was given once and only once by some individual as the response to *and* (or to *are*) in the course of the first ten occurrences of *and* (or of *are*). By these same individuals in the course of the next ten occurrences these same numbers were given as responses again with the following frequencies: 0 (that is never), 204 instances; 1 (that is, just as often as in the first ten), 163 times; 2, 76 instances; 3, 29 instances; and so on. In the third ten occurrences of *and* (or *are*) the numbers given once in the first ten are given never in 242 instances, once in 137, twice in 74, and so on. If we compute the average frequency for each ten, for response to *and* (or *are*) for these cases where the response was given once in the first ten, they are 1.00, 1.02, .92, .92, and .95, as shown in Table 40, page 36. There is thus little weakening of these initially weak tendencies.

Looking down the tables, we find next the history of the 276 responses to *and* (or *are*) which were given twice by the same individual in the first ten occurrences. Next below come the facts for the 129 which were given three times in the first ten. The average frequency for these in successive tens is 3.00, 1.44, 1.69, 1.71, and 1.70 as shown in Table 40.

The frequencies in successive 10's are due in part to other causes than frequency in previous 10's. For example, individual number 3 as a rule entered as the number for any of these eight words the number of letters composing it, using 3 for *and, are, the,* and *but* 166 times out of 190, and using 2 for *in, is, be,* and *of* 133 times out of 159. Ten individuals did this from some point in the series

TABLE 38

THE RESPONSES OF SUBJECT 1 TO *and*, *are*, *in*, *is*, *the*, *be*, *of* AND *but* ARRANGED BY SUCCESSIVE 10'S

Response to *and*	Frequency in 1st 10	2nd 10	3rd 10	4th 10	5th 10
1	5	2	3	4	
2	1	2	1	2	3
3		1			3
4	2	3	3	3	2
5			1		1
6			1		
7	2		1	1	1
8		2			
9					

Response to *are*	Frequency in 1st 10	2nd 10	3rd 10	4th 10	5th 10
1	2	5	3	2	4
2	2	1	2	1	1
3	2	2	1	4	1
4				1	2
5	1	1			
6					1
7	3	1	2		
8				1	1
9			2	1	

Response to *in*	Frequency in 1st 10	2nd 10	3rd 10	4th 10
1	2	6	6	5
2	1			
3	2	1	1	
4	2		1	3
5				
6	1	1		1
7	1	1		1
8			1	
9	1	1	1	

Response to *is*	Frequency in 1st 10	2nd 10	3rd 10	4th 10
1	3	6	4	7
2	3		2	2
3	1	1	2	1
4	3	1		
5				
6		2	1	
7				
8				
9			1	

Response to *the*	Frequency in 1st 10	2nd 10	3rd 10	4th 10	5th 10	6th 10
1	2	3	1	1	4	1
2	1	3	3		1	
3	4		1	6	3	4
4		1			1	3
5	1					
6		1				
7	1	1	3	1		
8	1	1	1	2	1	
9			1			2

Response to *be*	Frequency in 1st 10	2nd 10	3rd 10	4th* 10
1	1	2		
2	1	5	6	8
3	2	1		1
4	1			
5				
6		1	1	
7	1		1	
8	2	1	2	
9	2			

Response to *of*	Frequency in 1st 10	2nd 10	3rd 10	4th 10
1	7	6	4	4
2		2		1
3			1	2
4	1		2	2
5				
6	1			
7			2	
8	1	2		
9			1	1

Response to *but*	Frequency in 1st 10	2nd 10	3rd 10
1	5	4	2
2	2	1	2
3	1	4	3
4		1	1
5	1		
6	1		
7			2
8			
9			

* Only 9 responses.

TABLE 39

WORD NUMBER EXPERIMENT: THE HISTORY OF RESPONSES ACCORDING TO THEIR FREQUENCY IN THE FIRST 10 OCCURRENCES

Responses to *and* and *are*: Frequency	Occurrences in Successive Tens: 1st	2nd	3rd	4th	5th
0		204	242	253	262
1	494	163	137	132	123
2		76	74	66	62
3		29	27	19	20
4		12	5	10	11
5		9	1	5	4
6			2	3	3
7			1	2	1
8			2	1	1
9		1	2	2	4
10			1	1	3
0		98	103	125	133
1		85	84	74	70
2	276	54	48	33	32
3		25	22	14	18
4		8	7	15	6
5		4	2	5	2
6		1	2	1	4
7			4	1	4
8			3	3	1
9		1	1	1	2
10				4	4
0		36	44	46	44
1		45	36	37	37
2		25	18	13	24
3	129	10	11	12	9
4		6	11	9	2
5		5	5	3	2
6		1	1	1	2
7		1	2	2	3
8				4	
9				2	4
10			1		2

Responses to *the*: Frequency	Occurrences in Successive Tens: 1st	2nd	3rd	4th	5th	6th
0		78	95	91	106	118
1	209	70	65	58	59	42
2		35	23	36	23	24
3		19	15	11	6	11
4		6	4	4	7	5
5		1	3	3	1	1
6				4	3	1
7			3		2	4
8			1	1		
9				1	1	2
10					1	1
0		41	55	52	58	56
1		48	35	37	35	34
2	131	22	15	22	15	22
3		10	9	4	8	6
4		7	8	8	6	7
5		2	2	4	3	1
6			1	3	1	
7		1	3		1	1
8					2	2
9			2			1
10			1	1	2	1
0		12	18	10	15	22
1		15	13	21	12	10
2		11	7	5	12	7
3	48	6	5	6	4	5
4		3	2	1	1	
5			2	1	1	
6		1		1	1	
7				1		2
8			1	1	1	1
9				1		
10					1	1

Responses to *in*, *is*, and *of*: Frequency	Occurrences in Successive Tens: 1st	2nd	3rd	4th
0		272	316	341
1	704	247	213	186
2		119	109	106
3		47	39	38
4		14	10	13
5		3	12	9
6		2	3	3
7				3
8			2	5
9				
10				
0		116	138	165
1		137	120	106
2	404	89	78	71
3		36	32	22
4		17	15	16
5		3	8	10
6		5	4	2
7		1	4	3
8			1	4
9			1	2
10			3	3
0		36	51	57
1		40	35	42
2		36	26	22
3	150	21	12	11
4		10	13	6
5		5	4	3
6		2	1	4
7			3	2
8				2
9			1	
10			1	1

Total: Frequency	Occurrences in Successive Tens: 1st	2nd	3rd	4th
0		554	653	685
1	1407	480	415	376
2		230	206	208
3		95	81	68
4		32	19	27
5		13	16	17
6		2	5	10
7			4	5
8			5	7
9		1	2	3
10			1	1
0		255	296	342
1		270	239	217
2	811	165	141	126
3		71	63	40
4		32	30	39
5		9	12	19
6		6	7	6
7		2	11	4
8			4	7
9		1	4	3
10			4	8
0		84	113	113
1		100	87	100
2		72	51	40
3	327	37	28	29
4		19	26	16
5		10	11	7
6		4	2	6
7		1	5	5
8			1	7
9			1	3
10			2	1

TABLE 39 (*Continued*)

Responses to *and* and *are*

Frequency	1st	2nd	3rd	4th	5th
0		4	3	8	10
1		6	8	4	5
2		4	3	2	1
3		3	4	4	2
4	25	6			
5		1	1		
6			2	1	1
7					
8				1	
9		1	1		2
10			3	5	4
0		0	2	3	5
1		1	1	1	1
2		4	1	2	3
3		5	6	3	
4		3	1	3	2
5	21	2	3	1	
6		1	2	2	3
7		4	2	2	2
8		1			1
9			2	2	1
10			1	2	3
0		0	0	1	2
1		1			
2					
3			1	1	
4		3			
5					1
6	8				1
7		1		1	
8		1	2	1	2
9		2	3	2	
10			2	2	2

(Columns 1st–5th: Occurrences in Successive Tens)

Responses to *the*

Frequency	1st	2nd	3rd	4th	5th	6th
0		7	10	7	9	10
1		7	6	6	4	2
2		3	2	3	2	3
3		1	1	2	5	1
4	23	3		1		3
5		1		1		1
6		1	1	2	1	
7					1	
8			2	1		3
9			1			
10					1	
0					1	1
1			1	1	1	1
2		2	3	1	1	
3		1	1			
4		2		3	1	1
5	5					1
6					1	1
7						
8						
9						
10						
0						1
1						1
2		2	1	1	1	
3			1	1	2	1
4				1		
5						
6	3					
7			1			
8						
9		1				
10						

(Columns 1st–6th: Occurrences in Successive Tens)

Responses to *in*, *is*, and *of*

Frequency	1st	2nd	3rd	4th
0		6	8	9
1		12	6	13
2		6	11	7
3		6	6	5
4	40	7	2	1
5		1	2	
6		1	2	1
7		1	2	2
8			1	2
9				
10				
0		2	3	4
1		3	2	5
2		5	2	1
3		1	5	1
4		3	3	1
5	20	2	1	2
6				
7		1	1	3
8				1
9		2	2	1
10		1	1	1
0				
1				
2				
3				
4				
5		1		
6	3			
7		1		
8				
9		1	1	
10			2	3

(Columns 1st–4th: Occurrences in Successive Tens)

Total

Frequency	1st	2nd	3rd	4th
0		17	21	24
1		25	20	23
2		13	16	12
3		10	11	11
4	88	16	2	2
5		3	3	1
6		2	5	4
7		1	2	2
8			3	4
9		1	2	
10			3	5
0		2	5	7
1		4	4	7
2		11	6	4
3		7	12	4
4		8	4	7
5	46	4	4	3
6		1	2	2
7		5	3	5
8		1		1
9		2	4	3
10		1	2	3
0				1
1		1		
2		2	1	1
3			2	2
4		3		1
5		1		
6	14			
7		2	1	1
8		1	2	1
9		4	4	2
10			4	5

(Columns 1st–4th: Occurrences in Successive Tens)

Responses to *and* and *are*

Frequency	Occurrences in Successive Tens 1st	2nd	3rd	4th	5th
0					
1					1
2				1	
3					
4					
5					
6			1		
7	2	1			
8		1	1		1
9				1	
10					

Responses to *the*

Frequency	Occurrences in Successive Tens 1st	2nd	3rd	4th	5th	6th

Responses to *in*, *is*, and *of*

Frequency	Occurrences in Successive Tens 1st	2nd	3rd	4th
0				
1			1	
2				1
3		1	2	
4		1		1
5			1	
6		1		
7	5			2
8				
9		2	1	
10				1
0				
1				
2				
3				
4				
5				
6				
7				
8	2	1		
9			1	2
10		1	1	
0			1	1
1		1		
2				
3				
4				
5				
6				
7				
8				
9	2			
10		1	1	1

Total

Frequency	Occurrences in Successive Tens 1st	2nd	3rd	4th
0				
1			1	1
2				1
3		1	2	
4		1		1
5			1	
6		1	1	
7	7	1		2
8		1	1	1
9		2	1	
10				1

of 960. Individual 85 adopted the custom of entering 8 for any of the commonly repeated words of the 960, and entered 8 125 times out of 150 thereafter. It was for many a hard task to think of numbers fast enough to keep up, and anything which relieved it was welcome. When it became almost positive that certain words would recur again and again, there was a strong tendency to accept any plan which provided an easily obtained response to any one of them. The series was defective in being so short that the same word too often was repeated after a very brief interval so that an individual could think, "I just called that 4 and to save trouble will do so now and hereafter." There was thus in general a chance for the action of the law of exercise to be complicated by that of the law of effect, the latter acting probably on the whole in the direction of progressively increasing the frequency of the frequent, since doing so eased the task. There was (probably in a much less degree) the tendency to become bored by continually entering the same number for a given word and to use a different number to relieve this monotony. Sixteen individuals (3, 35, 37, 61, 85, 89, 91, 95, 111, 125, 137, 157, 163, 169, 191, and 201) were not included in the computation of Table 39, because it seemed certain that their responses were determined by causes irrelevant to our problem.

It would perhaps be desirable to eliminate certain other cases which, from the records and from the subjects' testimony, were influenced by factors other than repetition; but it seems best on the whole to retain them and allow for them later. Every one of the individuals may have been so influenced to some extent. No sharp separation is trustworthy.

The entries of Table 39 give only a rough view of the facts because they do not tell just what the responses of any given frequency had to compete with. A response with a frequency of 4, for example, which competes with two with a frequency of 3 each, may be expected to gain less

from them than a response with a frequency of 4 which competes with six with a frequency of 1 each. We shall present a better treatment later.

It should be noted further that records of, say, 1, 2, 5, and 8 occurrences out of 10, do not mean strengths in the exact proportions 1, 2, 5, and 8. Ten occurrences of a situation are not enough to measure at all precisely the strength of the connections leading from it. If by a miracle all influences of frequency could be suspended and the situation could be repeated a thousand times, responses which occurred 0, 1, 2, 3, and 4 times, respectively, in the first ten would probably not occur 0, 1, 2, 3, and 4 times in each later ten.

There are two questions, each important. The first asks how far the connection observed to be the most frequent gains at the expense of connections observed to be less frequent. It does not concern itself with the extent to which the observed frequency is a measure of a real and general strength of the connections. If two connections occur 6 and 4 times, respectively, it seeks to trace their future, inquiring whether the "6" gains at the expense of the "4," even though the "6" and the "4" are really of equal strength in general, being 1 too high and 1 too low in their particular experiment by "chance."*

The other question treats frequency in any short series as a symptom of inner conditions of general strength of connection which, subject to such "chances," cause one response to occur oftener than another. It argues from the general variability of response that, in a short series, say of ten, the lowest observed frequencies will be those of least general strength which chance reduced most, while the highest observed frequencies will be those of greatest general strength which chance increased most. If chance could be removed, the variability would be reduced. It asks what the effect of repetition of a situation is upon the

* Chance here refers, of course, to causes of variation not otherwise allowed for, not to anything essentially random.

TABLE 40

MEDIAN AND AVERAGE FREQUENCY OF OCCURRENCE IN LATER TENS OF RESPONSES OCCURRING ONCE, TWICE, THREE TIMES, FOUR TIMES, FIVE TIMES, AND SIX TIMES, RESPECTIVELY, IN THE FIRST TEN

The upper line of entries gives the medians; the lower line gives the average

Responses to *and* and *are*

Freq. in First Ten	Frequencies in 2nd	3rd	4th	5th
1	.76	.54	.48	.44
	1.02	.92	.92	.95
2	.92	.91	.68	.57
	1.25	1.29	1.27	1.23
3	1.15	1.07	1.00	1.05
	1.44	1.60	1.71	1.70
4	2.13	2.00	1.75	1.00
	2.44	3.28	3.36	3.08
5	3.67	4.00	4.00	4.25
	4.19	4.48	4.81	4.48
6	5.50	8.83	8.50	7.00
	5.75	8.25	7.00	6.00
7	7.50	7.00	5.50	4.50
	7.50	7.00	5.50	4.50
8 and 9				

Responses to *the*

Freq. in First Ten	Frequencies in 2nd	3rd	4th	5th	6th
1	.88	.65	.73	.49	.39
	1.08	1.03	1.12	0.99	1.00
2	1.01	.80	.87	.71	.78
	1.28	1.44	1.32	1.35	1.31
3	1.30	.96	1.17	1.25	.70
	1.53	1.42	1.83	1.69	1.48
4	1.14	.75	1.25	1.13	1.25
	1.70	1.91	2.04	2.00	2.26
5	3.00	2.00	3.67	2.00	4.00
	3.00	2.00	3.00	2.60	3.20
6	2.25	3.00	3.00	2.75	1.00
	4.33	4.00	3.00	2.67	1.33

Responses to *in*, *is* and *of*

Freq. in First Ten	Frequencies in 2nd	3rd	4th
1	.82	.67	.56
	1.01	0.97	0.98
2	1.13	1.03	.85
	1.34	1.41	1.34
3	1.48	1.13	.93
	1.68	1.63	1.48
4	1.83	2.14	1.35
	2.20	2.45	2 05
5	2.50	3.10	2.50
	3.65	3.65	3.60
6	7.00	9.75	10.00
	7.00	9.67	10.00
7	6.00	3.25	6.75
	6.20	4.20	6.00
8 and 9	9.00	9.50	9.00
	7.25	7.25	7.00

generally strong versus the generally weak connections. To answer it we need to allow for the disturbances caused by chance.

The second question is the more important, and we shall pay most attention to it. The first question is not, however, an idle one, for the advocates of the doctrine that repetition produces modifiability would probably in many cases not consider the chance element, but would simply assert that repetition makes the frequent wax at the expense of the infrequent response to the same situation. Moreover, the case where the early responses are *all* due to "chance" may be a very important case for practice.

Tables 39 and 40 answer the first question. If we use them at all to answer the second, we must remember that the real strength of the various connections will be greater than the face value of the frequencies shows for the less frequent, and less than the face value of the frequencies shows for the more frequent. Zero frequency in the first ten, for example, does not mean zero strength, but in the long run something more than that and a frequency of 7 in the first ten does not mean a strength of 70 percent, but in the long run a strength of less than that. We need not for the present decide how far the frequencies of responses to *and* in the first 10 measure the strength of the initial connections from *and* to 1, 2, 3, 4, 5, 6, 7, 8, and 9, respectively, and how far they are due to these initial connections plus various forces acting, some in a substantially random manner, during the period which included the first 10 appearances of *and*. They certainly are due in large measure to such forces.

The medians for successive tens (counting 1 as equaling the interval from 0.5 to 1.5, 2 as equaling the interval from 1.5 to 2.5, etc.) computed from Table 39 are shown in Table 40. The averages for successive tens are also shown in Table 40. The most important fact is that the connections with a frequency of 2 or 3 or 4 or 5 in the first ten all lose at the expense of the connections with a frequency

TABLE 41

THE AVERAGE NUMBER OF OCCURRENCES, IN EACH TEN AFTER THE FIRST TWENTY, OF RESPONSES WHICH OCCURRED 5 TIMES, 6 TIMES, 7 TIMES, AND SO ON IN THE FIRST TWENTY

In comparison with similar facts for responses which occurred 0 times, 1 time, 2 times, and so on in the first twenty, in the same individual, to the same word

Responses to *and* and *are*							
1st 20	3rd 10	4th 10	5th 10	1st 20	3rd 10	4th 10	5th 10
5	1.50	1.94	2.23	0	.80	.79	.77
	1.58	1.90	2.24	1	.78	.82	.72
	1.42	1.81	1.93	2	1.12	1.06	1.05
	1.36	1.79	1.97	3	1.32	1.19	1.18
	1.75	1.95	2.39	4	1.54	1.50	.93
6	3.08	2.41	2.61	0	.69	.51	.43
	2.26	2.65	2.32	1	.75	.79	1.09
	1.84	1.81	2.08	2	.95	1.34	1.03
	2.84	2.44	2.72	3	1.13	.88	1.06
	2.42	1.53	1.79	4	1.32	1.42	1.37
	3.88	4.50	4.00	5	1.38	1.25	1.00
7	2.84	2.32	3.00	0	.68	.76	.96
	2.88	2.38	1.94	1	.59	.69	.78
	2.61	2.65	2.74	2	1.06	.90	.71
	2.67	2.83	2.25	3	.83	.83	1.08
	3.00	1.56	2.44	4	1.33	2.11	1.78
	2.50	2.00	0.00	5	1.50	1.50	1.50
	4.00	4.00	9.00	6	4.00	6.00	1.00

Responses to *the*									
1st 20	3rd 10	4th 10	5th 10	6th 10	1st 20	3rd 10	4th 10	5th 10	6th 10
5	1.32	1.95	1.77	1.64	0	.82	.50	.68	.95
	1.78	2.39	2.01	1.78	1	.78	.72	.78	.81
	1.47	2.31	1.94	1.44	2	1.26	1.03	1.06	.91
	1.74	2.22	1.98	1.96	3	1.07	1.22	.89	.93
	1.50	2.25	2.08	1.50	4	1.67	1.58	2.17	2.42
6	3.94	3.72	3.38	3.16	0	.47	.41	.47	.47
	3.79	3.31	3.46	3.21	1	.51	.46	.67	.72
	3.84	3.75	3.66	3.53	2	.59	.78	.69	.56
	4.24	2.90	2.76	2.57	3	1.00	1.67	1.10	1.48
	2.38	2.77	2.08	1.92	4	2.00	1.77	2.08	2.00
	5.43	5.00	6.00	5.29	5	1.29	.43	1.00	.71
7	2.82	2.53	2.00	1.94	0	.71	.94	1.06	.88
	3.27	2.47	1.67	1.20	1	.60	.67	.67	.73
	1.94	1.81	1.25	1.50	2	1.19	.88	1.31	1.31
	2.91	2.82	2.09	1.91	3	1.00	1.27	.91	1.09
	1.00	1.00	2.00	0.00	4	7.00	5.00	5.00	7.00
	3.75	2.75	2.00	2.00	5	.00	.50	.50	.25
					6				

Responses to *in*, *is*, and *of*					
1st 20	3rd 10	4th 10	1st 20	3rd 10	4th 10
5	2.08	2.00	0	.51	.66
	1.94	1.69	1	.71	.88
	1.84	1.48	2	1.15	1.02
	1.94	1.78	3	1.21	1.09
	2.26	2.23	4	1.63	1.75
6	2.42	2.51	0	.55	.56
	2.63	2.74	1	.89	.86
	2.50	2.64	2	.87	.99
	2.26	2.95	3	1.12	.90
	2.58	2.60	4	1.20	1.32
	2.63	2.44	5	1.56	1.31
7	3.16	3.25	0	.64	.84
	2.66	2.42	1	.83	.51
	2.94	3.14	2	.98	.96
	2.97	2.77	3	1.10	1.40
	4.07	4.27	4	1.20	1.13
	2.00	1.57	5	.71	.71
	1.00	.00	6	.00	3.00

Responses to *and*, *are*, *the*, *in*, *is*, and *of* combined					
1st 20	3rd 10	4th 10	1st 20	3rd 10	4th 10
5	1.78	1.97	0	.65	.68
	1.78	1.86	1	.75	.84
	1.64	1.71	2	1.16	1.04
	1.68	1.85	3	1.24	1.15
	2.02	2.16	4	1.61	1.66
6	2.95	2.73	0	.58	.51
	2.88	2.96	1	.82	.81
	2.51	2.54	2	.85	1.08
	2.84	2.78	3	1.10	1.05
	2.48	2.28	4	1.42	1.46
7	3.02	2.89	0	.66	.84
	2.81	2.42	1	.73	.58
	2.67	2.76	2	1.04	.93
	2.89	2.79	3	1.02	1.25
	3.56	3.16	4	1.48	1.64

8	3.42	3.50	3.10	0	.48	.28	.64
	3.62	3.21	3.10	1	.62	.66	.66
	3.66	3.37	3.10	2	.89	.95	1.11
	4.71	4.29	4.14	3	.43	1.14	1.00
	3.75	3.00	1.50	4	3.00	2.50	2.50
	6.00	5.00	9.00	5	3.00	4.00	1.00
				6			
	1.00	2.00	0.00	7	0.00	0.00	1.00
9	3.22	4.84	4.11	0	.39	.22	.39
	3.00	4.40	4.40	1	.40	.67	.20
	3.33	4.17	3.50	2	1.00	.50	0.00
	1.50	5.00	3.50	3	.50	1.00	.50
	4.33	9.33	8.67	4	2.33	.00	.67
	2.67	3.00	3.00	5	3.00	1.33	3.67
	3.00	0.00	0.00	6	6.00	10.00	10.00
10	7.44	7.89	8.67	0	.22	.11	.00
	7.00	8.50	8.25	1	.50	.13	.13
	8.33	7.67	7.00	2	.00	.00	.00
	6.00	7.00	9.00	3	.00	.50	.00
	9.00	7.00	6.00	4	1.00	3.00	4.00
	7.00	9.00	9.00	6	1.00	1.00	1.00
11	6.00	6.00	7.00	0	1.00	.33	.50
	6.50	7.50	7.00	1	.25	1.00	.50
	5.40	3.80	7.00	2	.20	.40	.20
	7.00	9.00	7.00	4	.00	.00	.00

8	2.00	3.18	4.27	3.45	0	.73	.73	.36	.27
	2.18	3.29	3.76	3.24	1	.53	.94	.94	.65
	1.50	2.10	2.50	2.10	2	1.60	1.00	1.30	1.70
	2.14	2.86	3.43	2.57	3	1.29	.71	.29	1.43
	2.50	3.00	3.00	3.50	4	2.50	1.00	1.50	.50
	2.00	6.00	10.00	8.00	5	1.00	1.00	.00	.00
9	3.69	3.56	4.19	3.69	0	.44	.44	.50	.38
	4.29	4.71	5.71	4.86	1	1.43	1.14	1.00	1.57
	4.71	4.86	6.00	5.57	2	.57	.57	.57	1.14
	4.14	3.71	4.57	4.14	3	.71	.71	.29	.14
	4.00	4.50	5.50	4.00	4	2.00	2.00	1.50	.50
	1.00	1.00	.00	.00	5	.00	2.00	2.00	2.00
10	8.00	4.00	3.00	8.00	0	.00	.33	.00	.00
	8.00	4.00	3.00	8.00	1	.00	.00	.50	.00
					2				
	8.00	4.00	3.00	8.00	3	1.00	4.00	6.00	.00
					4				
	8.00	4.00	3.00	8.00	5	1.00	1.00	.00	2.00

8	4.41	3.83	0	.39	.41
	3.97	3.81	1	.65	.73
	4.51	4.05	2	.73	.83
	4.25	4.25	3	1.06	.94
	3.67	3.56	4	1.33	1.00
	5.50	3.00	5	.00	.00
			6		
	5.00	2.00	7	2.00	7.00
9	4.82	4.64	0	.27	.23
	5.65	3.24	1	.59	.71
	4.75	4.58	2	.75	.75
	5.86	4.57	3	1.14	1.29
	5.50	6.75	4	.75	2.00
	3.00	0.50	5	1.50	1.50
10	3.50	4.75	0	.94	.06
	3.82	5.00	1	.64	.45
	3.14	5.43	2	.29	.29
	4.33	6.00	3	.67	2.00
			4		
	5.50	6.00	5	.00	1.50
	.00	.00	6	6.00	8.00
11	5.33	6.33	0	.44	.33
	4.67	6.00	1	.44	.67
	7.33	7.33	2	.67	.33
	9.00	10.00	3	.00	.00
	4.00	2.00	4	.00	1.00
	3.00	7.00	5	4.00	.00

8	3.79	3.64	0	.46	.41
	3.48	3.49	1	.61	.75
	3.84	3.58	2	.90	.88
	3.87	3.93	3	.97	.93
	3.53	3.33	4	1.93	1.40
9	3.98	4.34	0	.36	.29
	4.38	3.95	1	.67	.77
	4.40	4.56	2	.76	.64
	4.56	4.25	3	.88	1.00
	4.78	7.11	4	1.56	1.33
10	5.25	5.68	0	.61	.12
	5.43	5.86	1	.52	.29
	4.70	6.10	2	.20	.20
	5.60	5.60	3	.50	1.83
	9.00	7.00	4	1.00	3.00
11	5.60	6.20	0	.67	.33
	5.23	6.46	1	.38	.77
	6.13	5.13	2	.38	.38
	9.00	10.00	3	.00	.00
	5.50	5.50	4	00	50

of 0 in the first ten. A connection which has a frequency of 6 or more in the first ten just about holds its own. A frequency of 4 or 5 in the first ten is thus not strong enough to overcome the "various forces" mentioned in the previous paragraph.

Consider now a treatment which reduces the effect of chance by using the first twenty instead of the first ten, and which compares always the most frequent responses in early trials with each competing response one at a time, and which uses as the most frequent response no case in which the frequency for the first twenty is less than five, or two and a half times what mere chance alone would give.

In this computation we have also arranged matters so that each individual's records are kept separate, and the later histories of the responses which occurred often or seldom in the first twenty appearances of the word are compared always within the same individual. Tables 41 and 42 show the results. Responses with a frequency of 12 or more in the first twenty are reported separately in Table 42. There are few such, only six individuals in the case of *and* and *are*, two in the case of *the*, and twelve in the cases of *in*, *is*, and *of*.

For frequencies in the first twenty from 5 up to 10, the most frequent uniformly loses in later tens. For frequencies of 10 or more there is on the whole a slight gain of the more frequent, at the expense of the less frequent. Our inspection of the individual records shows that this gain is due to certain responses becoming the exclusive responses to certain words, with frequencies of 10 out of 10. This is probably a consequence of the satisfyingness of having one ready response fixed in memory rather than a product of mere frequency. Competing responses with a frequency of 3 or 4 in the first twenty also lose ground in later tens. The twos about hold their ground. The ones and zeros gain. They presumably were unduly low by chance.

TABLE 42

SAME AS TABLE 41, BUT FOR RESPONSES WITH A FREQUENCY OF 12 OR MORE IN THE FIRST 20, AND WITHOUT THE REPORT FOR THE RESPONSES TO ALL SIX WORDS COMBINED

Responses to *and* and *are*

1st 20	3rd 10	4th 10	5th 10	1st 20	3rd 10	4th 10	5th 10
13	8.07	4.73	4.47	0	.33	.60	.67
	8.00	6.87	5.75	1	.13	.38	.63
	7.75	5.13	5.88	2	.25	.88	.63
				3			
	9.00	3.00	.00	4	.00	.00	.00
14	6.00	2.00	1.00	0	.75	1.50	2.00
	6.00	2.00	1.00	1	.50	.50	.50
	6.00	2.00	1.00	2	.00	.50	.00
15	8.00	9.00	8.00	0	.00	.00	.50
	8.00	9.00	8.00	1	.00	.33	.00
	8.00	9.00	8.00	2	2.00	.00	.00

Responses to *the*

1st 20	3rd 10	4th 10	5th 10	6th 10	1st 20	3rd 10	4th 10	5th 10	6th 10
15	8.27	7.82	7.45	6.82	0	.36	.45	.45	.73
	7.00	4.00	3.00	3.00	1	.00	.00	.67	.00
	7.00	4.00	3.00	3.00	2	.00	1.00	.00	.00
					3				
	9.00	10.00	10.00	9.00	4	.00	.00	.00	.00

Responses to *in*, *is*, and *of*

1st 20	3rd 10	4th 10	1st 20	3rd 10	4th 10
12	10.00	9.00	0	.00	.00
	10.00	9.00	1	.00	.00
	10.00	9.00	2	.00	.50
13	6.50	7.00	0	.50	.38
	6.50	7.00	1	.50	.50
	6.50	7.00	2	.00	.50
	6.50	7.00	3	.00	.00
14	6.92	6.42	0	.25	.42
	6.00	6.00	1	.63	.63
	7.33	7.00	2	.33	.00
	7.00	6.00	4	1.00	1.00
15	9 55	10.00	0	.09	.00
	9.00	10.00	1	.00	.00
	9.33	10.00	2	.00	.00
	10.00	10.00	4	.00	.00
16	6.33	7.07	0	.73	.53
	6.33	6.67	1	.00	.17
	6.33	7.33	2	.00	.00
19	10.00	10.00	0	.00	.00
	10.00	10.00	1	.00	.00

Let us now consider the probable strength of the connections in the mind rather than the actual frequencies in the records; that is, let us eliminate the influence of the chance errors which make the frequencies imperfect measures of the strengths of the connections. This is conveniently done by using the gain from the third to the fourth ten, from the fourth to the fifth ten, and from the fifth to the sixth ten, of connections which were of various frequencies in the first twenty.

The real general strength of the connections will be correlated positively, though not perfectly, with their observed frequencies in the first twenty. The average frequency in the third or any later ten of any group of connections chosen by their frequencies in the first twenty will be as much raised as lowered by chance. It will vary from the truth in a random manner. If the stronger gain at the expense of the weaker, the more frequent in the first twenty should gain more than their less frequent competitors from the third ten to the fourth ten, from the fourth ten to the fifth, and so on, and should gain oftener than they. Since there is ambiguity in comparing the amounts of gains from different starting points, we use the presence or absence of gain as our measure.

We use first the gains from the third to the fourth ten found for *and, are, the, in, is,* and *of* all together, comparisons being available of 5 with 0, 1, 2, 3, and 4, of 6 with 0, 1, 2, 3, 4, and 5, and so on. The connections with frequencies of 5 to 9 in the first twenty showed gains from the third to the fourth ten in 13 out of the 25 cases, one being, however, only a gain from 3.48 to 3.49. In 12 cases there was a loss. The connections with frequencies of 0 to 4 in the same individuals showed gains from the third to the fourth ten in 11 cases and losses in 14 cases, one of the latter being a drop from .82 to .81.* The connections

* These results and all those given in the next five paragraphs are unweighted for the number of individuals in the comparisons. We shall consider the question of weighting later.

with a frequency of 10 or 11 in the first twenty showed gains from the third to the fourth ten in 6 out of the 10 cases, with 2 equals, and 2 losses. The connections with frequencies of 0 to 4 in the same individuals showed 4 gains, 3 equals, and 3 losses.

In the case of the gain from the fourth to the fifth ten, using the records from *and, are,* and *the,* we find the following: The strong connections (5 to 9 in the first 20) show 27 gains, 4 equals, and 30 losses in the 61 opportunities. The weak connections (0 to 6, with one case of 7) in the same individuals show 24 gains, 10 equals, and 27 losses. The still stronger connections (10 and 11 in the first 20) show 8 gains, 1 equal, and 5 losses. The weak connections in the same individuals show 4 gains, 4 equals, and 6 losses.

The few scattering cases with frequencies of 13 to 15 in the first 20 show 1 gain and 13 losses for the strong connections; and 5 gains, 5 equals, and 4 losses for the weak connections, in the same individuals.

In all, for the change from the fourth to the fifth ten, we have 36 gains, 5 equals, and 48 losses for the originally strong connections, and 33 gains, 19 equals, and 37 losses for the originally weak connections.

Using the records for *the* for the fifth and sixth tens, we find the following: the strong connections (5 to 15) show 7 gains, 4 equals, and 26 losses; the weak connections (0 to 5) in the same individuals show 15 gains, 7 equals, and 15 losses.

The inference, so far as these comparisons may be trusted, is that on the whole the strong connections do not gain from the third ten on appreciably more than the weaker connections in the same individuals. The strong show 62 gains, 11 equals, and 88 losses; the weak show 63 gains, 29 equals, and 69 losses. In them, equal weight is given to the comparison of 5 in 20 with 0 in 20, 5 in 20 with 1 in 20, and so on, regardless of how many such pairs there were. This prevents the 5 and 6 and 7 connections among the strong and the 0 and 1 connections among the weak

from having the very great weight which they would have if each individual case of strong versus weak were counted as one. If this latter procedure is followed there is still no evidence of any gain of the strong at the expense of the weak. Nor will any reasonable system of weighting for the facts of Table 42, or for the individual records whence they are derived, show a balance of gain of the strong at the expense of the weak.

Experiment 24, reported in Appendix III, confirms the conclusions reached from Experiment 23.

Experiment 25

In Experiment 25, the external situations presented were the sounds of (1) *a* in *late*, (2) *ee* in *week*, (3) *ow* in *house*, (4) *o* in *home*, (5) *aw* in *lawn*, (6) *k* in *Kansas*, (7) *f* in *for*, and (8) *s* in *so*. The response was in each case to represent the sound by letters. The sounds appeared in the following eighty nonsense words which the subjects spelled in order:

1 kace eed'aub	21 kace'ok i	41 face'awk oz	61 face'our ate
2 weece'ol eet	22 fouce'awg ane	42 jode eez'ame	62 wot awf'ee
3 kawl awt eez'	23 toce'ail ot	43 sseel'om uce	63 sseel ame'ju
4 ro'ce ane our	24 koum aw'kox	44 foum ol'eek	64 joum ane eez'
5 kaze oud'ei	25 lo keen'eep	45 ssou mee'tawz	65 soz ou kawss'
6 ssaw paw'kee	26 jau pee'ku	46 wail·ok oun'	66 jom awn'i
7 faze' ou kane	27 ssout'ape awz	47 kom awd'sawn	67 kop ouk'eel
8 top awss'oun	28 lop'ate oul	48 feen'oul ite	68 reen aig'saw
9 ween ate og'	29 keen eez i'	49 kawf ou'jay	69 kawf'ee ssot
10 waig awb'ouz	30 aig eel'fane	50 jaig'ode une	70 kak eece'ele
11 keece oum'aw	31 feece awd'i	51 seece'og ate	71 jawl oun'att
12 eeg awm oun'	32 wawp eem'ou	52 foce op oun'	72 wail our'eet
13 ssawl'eet one	33 kaze'oup uss	53 laze'og ite	73 fom'eeg awt
14 kade ache'eep	34 ade awss'oup	54 faig oul ize'	74 ssaig'oce ote
15 kouce'eep i	35 keed on'iss	55 waw'lay ssu	75 wail awx'our
16 mo'foude ape	36 fo jawb ufe'	56 sso'tee maw	76 i jo'ssaw
17 ssace awx'our	37 wade'om ite	57 wide out'aze	77 jade een'ou
18 jouce ake'on	38 jee dail'ake	58 eeg'ame ou	78 o'fawl ong
19 wawn'ouz u	39 kaze'awt eeg	59 ssee law'gaw	79 ou sse'lace
20 koce eex'ay	40 jout eek'si	60 kou tu'life	80 fout awb'ate

In these words, *a* and *ay* and *ai* indicate (1); *ee* indicates (2); *ou* and *ow* indicate (3); *o* indicates (4); *au* and *aw* indicate (5); *k* indicates (6); *f* indicates (7); *s*, *ss* and *c* indicate (8); *g* is always hard; *i* is always as in *bite*; *u* is always long. The somewhat awkward writing of these nonsense words was to insure that they should be pronounced as intended. This entire series was heard and spelled at one sitting. The first half of it was heard and spelled again three weeks later.

One hundred one subjects (graduate students) underwent the experiment, but 17 records (for some sounds 18) were discarded because of illegibility or incompleteness, leaving 83 or 82. A sample record is shown in Table 48, together with the record computed from it of the number of occurrences of each response in each successive ten.

TABLE 48

RECORD OF SUBJECT AND'S RESPONSES TO THE SOUND Ā

Responses to *a*: in order

1st 10	2nd 10	3rd 10	4th 10	5th 10 (9)	6th 10	7th 10	8th 10 (6)
a	a	a	a	a	a	a	a
e	a	a	a	i	e	a	a
a	a	a	a	a	a	a	a
a	a	ae	a	ay	a	a	a
a	a	a	ee	ay	i	ai	ee
a	a	a	a	ay	a	a	a
ay	y	a	e	ay	a	ee	
a	e	a	a	a	a	a	
a	a	a	i	i	e	i	
a	ai	a	a		a	ai	

Frequencies in successive 10's

	1st 10	2nd 10	3rd 10	4th 10	5th* 10	6th 10	7th 10	8th 10
a	8	7	9	7	3.3	7	6	8.3
e	1	1		1		2		
ay	1				4.4			
y		1						
ai		1					2	
ae			1					
ee				1			1	1.7
i				1	2.2	1	1	

(The number for trials 41–49 for *a* and for trials 31–35 for *ee* and *s* is raised to what it would be on the base of ten.)

Let us first consider the facts for the sounds, *s, o* and *a*, for which the most frequent response in the first ten is usually *very* frequent, so that they offer a favored case for the strengthening of the strong connection at the expense of the weak.

S was for all individuals the most frequent spelling for the *s* sound in the first ten; 41 individuals wrote it 10 times, 30 wrote it 9 times, 7 wrote it 8 times, 5 wrote it 7 times, and 1 wrote it 6 times. It thus occurred 777 times out of a possible 840 in the first ten. In successive tens of the first sitting it occurred 785, 710, 719, and 712 times; and in the second sitting three weeks later it occurred 798 and 796 times.

O was also for all individuals the most frequent spelling for the *o* sound in the first ten; 17 individuals wrote it 10 times, 26 wrote it 9 times, 22 wrote it 8 times, 11 wrote it 7 times, 6 wrote it 6 times, and 2 wrote it 5 times. It thus occurred 703 times out of a possible 840. Its later occurrences numbered 672, 723, and 677 for the first sitting and 709 and 687 in the second.

A was written for the *a* sound in the first ten as the most frequent spelling by all except 1 case of *ae*, 1 of *ai*, and 6 of *e*. At least three, and perhaps more, of those writing *e* were foreign students for whom *e* was the natural spelling. There were four 10's, seventeen 9's, twenty 8's, twelve 7's, twelve 6's, fourteen 5's, three 4's, and one 3 (one individual's record was not used because of illegible responses). Out of a possible 830 we have a total of 594 for the most frequent responses in the first ten. The later frequencies of these responses in the same individuals during the first sitting are 463, 462, 537, and 387, and in the later sitting, 573, 413, and 488.

Combining the results for *s*, *o*, and *a*, we have 2094 out of a possible 2510 in the first ten and 2080 when these same words were spelled again in the second sitting. For the second ten we have 1920; and 1896 when the same words were spelled again in the second sitting. Even in this

favored case of a strength of over .80, the strong does not gain from the weak. The *status quo* is maintained.

The *e* sound has *e* as most common spelling in the first ten in 64 out of 83 individuals. The others are about

TABLE 49

THE FREQUENCIES OF THE RESPONSES TO *ou* AND *aw* WHICH WERE THE MOST FREQUENT IN THE FIRST TEN

F is the frequency of the most frequent response in the first ten. N is the number of individuals, displaying the given F. 1, 2, 3, 4, 1r and 2r are the total frequencies in the first and following tens, 1r and 2r referring to the repetitions of the first ten and second ten after three weeks.

Responses to *ou* as in *house*

F	N	1	2	3	4	1r	2r
9	3	27	18	16	24	15	22
8	6	48	23	29	40	27.4	39
7	13	91	52	60	63	55.8	70
6	16	96	37	38	43	33	41
5	14	70	47	36	44.2	40.3	43
4	21	84	45.2	55.2	56.4	51.8	57
3	10	30	15	9	14	14	16
2	1	2	1	0	1	1	1
Total	84	448	238	243	286	238	289

Responses to *aw* as in *lawn*

F	N	1	2	3	4	1r	2r
10	1	10	5	8	6	9	9
9	2	18	14	16	16	18	18
8	5	40	28	26	24.7	37	21
7	11	77	50	57	59	68	42
6	8	48	22	21	35	29.6	21
5	19	95	39	37	37	45	37
4	23	92	62	72	75	82	51
3	14	42	27	27	23	23	23
Total	83	422	247	264	276	312	222

equally divided between *ee* and *i*. There were five 9's, fourteen 8's, twelve 7's, seventeen 6's, eighteen 5's, twelve 4's, and three 3's, giving a total of 496 out of a possible 830. In later tens of the first sitting the frequencies were 387, 437, 435, and 355; and in the second sitting 474 and 397.

With the *ou* and *aw* sounds there is a greater variety

among the responses which were the most frequent in the first ten; their frequencies are lower; and they clearly lose in later tens to the initially less frequent. The facts are presented in Table 49.

The loss of the initially frequent to the initially rare in these eighty-four subjects in this experiment seems to be due partly to a general tendency to vary responses to the same sound and partly to tendencies to favor the simpler or least ambiguous spellings. We have computed the facts separately for *ou*, *ow*, *o*, *au*, *aw*, and *a* as responses to the *ou* sound, and for *o*, *a*, *au*, and *aw* as responses to the *aw* sound. The second tendency seems to be relatively weak.

Experiment 26

This experiment was an improved form of Experiment 25. The improvements consisted in using 240 words instead of 80, and in repeating them so that 480 words in all were spelled, containing 6 times as many occurrences of the sounds, and in extending the time from one day to twelve. Forty words were spelled each day except Saturdays and Sundays, for 12 days. The total occurrences were 294 for *a*, 268 for *e*, 246 for *ou*, 246 for *aw*, 236 for *o*, 210 for *k*, 124 for *f*, and 268 for *s*.

As the main record we use the first thirty responses and the last thirty for each sound except *f*, for which the first twenty and last twenty are used. The essential results appear in Table 50. The initially most frequent response gains in 25 cases, loses in 18, and remains the same in 5. The totals are 898.7 in the first thirty and 919 in the last thirty. The median change is between 29 to 30 and 28 to 29.

We have prepared and examined tables showing in detail the changes for each of the six subjects. By any reasonable treatment they show the same general result as that which appears in Table 50.

The gains are in general in the direction of more reasonable responses. Thus, for *a*, *e* loses to *a*; for *e*, *i* loses to *ee*; for *ou* as in house, *au* loses to *ow*. The changes are

better explained by the strengthening of the more satisfying connections than by the strengthening of the more frequent. There are also eccentric changes, such as a change from *o* to *oe* in the case of subject R, which are not easily explainable by either principle.

TABLE 50

THE INFLUENCE OF REPETITION UPON THE CONNECTIONS BETWEEN SOUNDS AND SPELLING

Column 1 gives the subjects; columns 2 and 3 give the spelling that was most frequent in the first 30, and its frequency there; column 4 gives its frequency in the last 30. In the case of *f*, the first and last 20 are used.

	a as in *hate*			*e* as in *delete*			*ou* as in *house*			*aw* as in *paw*		
1	2	3	4	2	3	4	2	3	4	2	3	4
C	a	15	28	i	17	4	au	11	0	au	11	0
M	a	24	24	ee	20	23	ow	18	25	aw	11	12
P	a	27	30	i	14.3*	12	au	16	5	au	12	3
R	a	16	28	e	9	2	ow	19	28	aw	20	13
S	a	16	30	e	21	21	au	9	1	au	15	10
W	a	15	25	i	28	23	au	18	18	au	19	17
Total		113	165		109.3	85		91	77		88	55

	o as in *so*			*k* as in *keg*			*f* as in *fan*			*s* as in *so*		
1	2	3	4	2	3	4	2	3	4	2	3	4
C	o	24	25	k	25	28	f	7	15	s	26	25
M	o	15	28	k	29	29	f	18	20	s	29	30
P	o	16	21	k	15.7*	26	f†	18	20	s	28	29
R	o	17	4	k	19	22	f	14	19	s	25	28
S	o	24	28	k	27	16	f	9	16	s	28	29
W	o	17	16	k	24	25	f	12.7*	11	s	30	27
Total		113	122		139.7	146		78.7	101		166	168

* One or more words being omitted or illegible, the number per 30 or per 20 was estimated from the 29 or 19.

† *f* occurred 9 times in the first 20, 19 in the last; *ph* occurred 9 times in the first 20, once in the last.

Experiment 27

Besides the experiments in responding to words by a number, and in responding to sounds by writing their spelling, we have carried out a series in which the situation was two or three letters, like *ba* or *cri*, the response being to write additional letters to make words. Each individual did 240 such each day for 14 days. There were 10 sheets,

which were used in order, after which the first 4 sheets were repeated. The instructions given were as follows:

Directions: Word Completion

When I say "Go," turn over the sheet and complete words for which the first two or three letters are given. Write in every case the first word you think of, beginning with these letters. I will record your time when you have finished, so please call my attention when you are through; but be sure to write clearly so there will be no doubt about what word you are writing.

"Word completion" again was used after a day or two, when they were familiar with the task.

The combinations *ab*, *ac*, *ad*, *af*, *ag*, *ai*, *am*, *an*, *ap*, *ar*, *as*, *at*, *au*, *bo*, *bu*, *bl*, *br*, *ca*, *ce*, *ci*, *co*, *cu*, *cha*, *che*, *chi*, and many others occurred twice each on each sheet, or 8 times on the first four sheets, 12 times on the next six sheets, and 8 times, of course, on the repeated four.*

Six college undergraduates, students of psychology, completed the experiment. For each we have a record with each combination of letters like that shown in Table 51 for Subject C, with combinations *ed*, *ef*, *eg*, and *el*.

Table 51

Sample record (for subject c), in experiment 27

ed		*ef*		*eg*		*el*	
First 8	Last 8	First 8	Last 8	First 8	Last 8	First 8	Last 8
ucate	ify	fect	fect	gs	g	evate	f
it	"	face	"	ad	"	ephant	"
ucate	"	fect	"	g	"	"	"
ify	"	"	"	o	"	evate	"
ucate	"	"	"	"	"	ephant	"
ify	"	"	"	g	"	"	"
ify	"	"	"	"	"	"	"
ify	"	fort	"	"	"	f	"

We then compute the frequency of each completion in the early eight and also in the late eight. We then trace the history in the late eight of the early completions of each degree of frequency. This was done separately for one-letter

* In a few instances the numbers were 9 and 13 instead of 8 and 12.

completions, two-letter completions, three-letter completions, and so on. The results are shown in Table 52. The average frequency of each in the late eight is reported in Table 53.*

The results show clearly that the most frequent response in the first eight does not grow at the expense of the less frequent responses, but that the few-letter responses grow at the expense of the many-letter responses. One-letter responses show an average gain, except when the initial frequency is 8, no matter how low their early frequencies are. When the initial frequency of the response is constant, the long completions lose to the short completions. The average changes for responses of one letter, two letters, three letters, etc., are respectively +1.39, —.22, —.85, —.88, —1.42, —2.63, and —2.00. When the length of the response is constant, there is no correlation of gain with initial frequency.

The average changes for responses of early frequencies of 1, 2, 3, 4, 5, 6, 7, and 8, respectively, allowing equal weight to each frequency and each length through 7, are in

* There is a certain objection to using averages for this material, in that there are so many 8's undistributed. There are, however, still stronger reasons against using the medians. Moreover, if the high early frequencies are somewhat penalized by the use of averages, they have a counterbalancing unfair advantage due to the fact that certain letter combinations are, for an individual at the time, very hard to complete into words, so that completions when found tend to be rather striking, to be fixed in memory and to be used uniformly thereafter. The frequency of these may be judged by the following list of the responses to the first forty-two combinations which had an initial frequency of 7 or 8 out of 8.

ab	*ag*	*aug*	*cha*	*ec*	*em*
absent	ago	augment	charade	economics	embroider
"	again	*bu*	*che*	*ed*	*ep*
"	*ai*	bucolic	cheat	edify	epitaph
"	ail	*bl*	*chi*	*ef*	epitome
ac	aigret	blow	child	effort	epileptic
accept	*am*	*br*	child	effort	*fe*
ad	amend	brown	*cho*	*eg*	feline
address	*an*	*ce*	chorus	egg	
add	another	cement	*du*	*el*	
af	and	certain	duty	elevator	
affect	*ar*	*cu*	*dr*	elf	
after	arrest	cut	draw		

order: —.48, —.71, —.66, —.95, —1.10, —1.83, —.39, and —1.59. If we use the median rather than the average for the group with initial frequencies of 8 because of the influence of the undistributed 8's, we have —.69 in place of —1.59. The material for completions of 8 to 11 letters is too scant to be included.

Table 52

The influence of repetition in completing words

1, 2, 3, 4, 5, 6, 7, and 8 across the page refer to the number of times a response was made in the first 8 occurrences of the situation. 0, 1, 2, 3, 4, etc., down the page refer to the number of times the given response was made in the last 8 occurrences of the situation. Thus, among one-letter completions, those occurring once in the first 8 displayed 69 zero occurrences in the last 8, 10 single occurrences, 4 double, 3 treble, 3 of four, 3 of five, 3 of six, 5 of seven, and 12 of eight.

	One-letter Completions								Two-letter Completions								Three-letter Completions							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
0	69	13	4	2	1			1	249	51	32	15	6	1			195	49	12	13	9	3		
1	10	1	5						17	6	2	3	1				14	4	3	3	2	5		
2	4	2	1						6	3	1	2	2	1	2		5	1	1		1			
3	3	1	1			1			2	1	1	1	1	1			2	3	2	2				1
4	3	3	1	1	1				4	1	3	2	1				3		3			1	1	
5	3	1	2	3	2				2	3		3		1			3		2	1				2
6	3	1	3	2	1	1			3	1	5		3	2	2		2	2		1	3			1
7	5	5	3	4	2	1	4		8	1	4	5	5	5	2	1		3	1	4	4	1	3	1
8	12	19	13	12	13	10	8	8	5	4	7	14	9	10	10	6	2	7	4	5	9	5	4	6

	Four-letter Completions								Five-letter Completions								Six-letter Completions							
0	159	39	17	12	4	3	2		88	20	9	4	5	4	1		54	17	8	2	1	3		1
1	6	6	1	4	2	2	1		2	2	2	3	5				1							
2	2	1	2	2	1				1	1	1	1						1						
3	2	2	1						1	1	1	2			1								1	
4	2			1	2										1						1	1		
5	2		2	1	1	2									1									
6		1	6	2	2					1			2	1										
7	2	2	6	2	1		2					2	1	1				1			1			
8	3		1	3	3	5	11	7				2	2	3	5	4			1		1	2	1	

	Seven-letter Completions								Eight-letter Completions								Nine, Ten, and Eleven-letter							
0	23	7	3	2	1	1			22	4		1					7		2					
1																								
2																								
3																								
4																								
5																								
6								1																
7				1																				
8	1		1				1	2																

In this experiment we see the power of satisfyingness compared with that of repetition. The ease of writing a short completion and the satisfaction of finishing a sheet quickly in the presence of others doing the same task put

a premium upon short completions, although there was no formal requirement of speed. The clear, consistent, and substantial influence of the length of the completion in this experiment is in striking contrast to the vague, casual, and slight possible influences of pure repetition which we have been able to find in this and other experiments.

Table 53

Completing words: the average frequency, in the last 8 repetitions, of a response according to its length and its frequency in the first 8

	1	2	3	4	5	6	7	8
One- letter	1.81	4.74	5 06	6.46	6.90	7.38	7 67	7.11
Two "	.65	1.11	2.42	4.00	4.89	6.52	6.78	7 86
Three "	.38	1.51	2.57	3.03	4 36	3.53	7 13	6 73
Four "	.40	.67	2.89	2.48	3 75	4.33	6 44	8 00
Five "	.08	.52	.54	2.93	2.67	4.11	5 78	8 00
Six "	.02	.47	.89	.00	4.75	3.33	5 50	0.00
Seven "	.33	.00	2.00	2.33	.00	.00	8.00	7.33
Eight "	.00	.00		1.00				
9, 10, 11 "	.00		.00					

In Experiments 25, 26, and 27, as in Experiments 1 to 24, the variability is reduced, though not by the waxing of the initially frequent at the expense of the initially rare. The reduction in the case of a random sampling consisting of sixty-three of the individuals of Experiment 25 on spelling is slight, being almost zero from the first ten to the corresponding ten three weeks later, and not very great from the second ten to the corresponding ten three weeks later. The facts are summarized in Table 54. The reduction in the case of the longer spelling experiment (26) is

Table 54

The reduction in variability in experiment 25: distributions of the frequencies of the frequencies 1 to 10

	In the First 10	In the Second 10	In the Corresponding Tens 3 Weeks Later First	Second
1 and 2	607	694	586	565
3 " 4	172	192	153	160
5 " 6	92	110	97	90
7 " 8	102	74	80	93
9 " 10	107	93	125	119

considerable, the facts being as shown in Table 55. The reduction is very great in the experiment (27) on completing words, as is shown in Table 56.

TABLE 55

THE REDUCTION IN VARIABILITY IN EXPERIMENT 26: DISTRIBUTIONS OF THE FREQUENCIES OF THE FREQUENCIES

	In the First 30	In the Last 30
1 to 5	136	104
6 " 10	32	16
11 " 15	15	7
16 " 20	15	10
21 " 25	8	14
26 " 30	10	19

TABLE 56

THE REDUCTION IN VARIABILITY IN EXPERIMENT 27: WORD COMPLETIONS DISTRIBUTIONS OF THE FREQUENCIES OF THE FREQUENCIES

	In the Early 8	In the Late 8
1	451	101
2	116	43
3	80	19
4	70	24
5	45	22
6	32	31
7	26	46
8	16	120*

* By reason of small discrepancies, the total frequencies are 1910 and 1918.

The facts of the word-number experiments (23 and 24) may be used to bear upon our problem in another way. We may consider the situation in Experiment 23 as being the sound of *any* word and the response as being the writing of any number from 1 to 9, and ask whether the numbers which are most frequently written, say in the first 160 appearances of the situation, gain thereafter at the expense of those less frequently written in the first 160.

We have tabulated the responses for each successive 160 of the 960 for eighteen individuals taken at random in the way shown in Table 57 for individual 2, so as to compare

TABLE 57

THE RESPONSES OF INDIVIDUAL 2 IN EXPERIMENT 23

Response	Frequencies in Successive 160's					
	1 to 160	161 to 320	321 to 480	481 to 640	641 to 800	801 to 960
1	4	5	8	11	12	11
2	27	29	40	29	40	36
3	38	45	44	35	42	46
4	26	23	19	18	19	22
5	18	22	13	12	13	25
6	15	5	7	14	14	2
7	9	9	6	9	2	2
8	9	12	5	10	3	7
9	14	10	18	22	15	9
2, 3, and 4	91	97	103	82	101	104
1, 7, and 8	22	19	19	30	17	20

TABLE 58

THE FREQUENCIES IN THE SECOND AND SIXTH 160'S OF THE RESPONSES WHICH WERE THE THREE MOST FREQUENT AND THE THREE LEAST FREQUENT IN THE FIRST 160 OF EXPERIMENT 23

The numbers in parentheses mark cases where 4, 2, or 1 was the number of responses instead of 3.

Individual	Frequency of the Three Highest in the First 160			Frequency of the Three Lowest in the First 160		
	1 to 160	161 to 320	801 to 960	1 to 160	161 to 320	801 to 960
1	77	87	68	23	23	26
2	91	97	104	22	19	20
3	92	95	65	20	17	66
4	79	71	77	19 (2)	24	19
5	99 (4)	81	85	27	49	64
6	74	62	57	32	43	40
7	102	89	76	15	17	48
8	97 (4)	106	116	29	19	21
9	72	72	50	36	38	49
10	76	60	72	32	35	30
11	84	68	74	27	29	27
12	77	52	64	38	54	59
13	62	48	51	28 (2)	34	48
14	64	65	57	42	47	51
15	89	85	82	12	39	19
16	99	85	63	18	23	39
17	77	68	66	35	36	34
18	90 (4)	77	80	38	57	64
Total 1 to 18		1368	1307		603	724

TABLE 58 (*Continued*)

Individual	Frequency of the Three Highest in the First 160			Frequency of the Three Lowest in the First 160		
	1 to 160	161 to 320	801 to 960	1 to 160	161 to 320	801 to 960
19	65	54	58	24 (2)	29	20
20	85	78	86	26	25	29
21	102 (4)	109	95	14	14	11
22	73	58	63	21 (2)	26	31
23	74	72	81	28	38	25
24	86 (4)	85	83	12 (1)	19	36
25	82	69	45	25	37	58
26	79	71	62	20 (2)	24	19
27	74	67	64	33	40	54
28	82	80	69	20	16	22
29	79	65	67	30	41	41
30	73	70	56	19 (2)	17	16
31	64	65	56	39	41	51
32	75	69	74	34	28	16
33	91	79	51	24	36	55
34	75	74	75	31	23	40
35	80	87	88	30	22	33
36	85	75	69	13 (2)	6	26
37	83	85	80	24	24	24
38	93	74	84	15 (2)	18	10
39	92	89	87	19	26	41
Total 19 to 39		1575	1493		550	658

the gains of the three most frequent with the gains of the three least frequent, and the three of middle frequency, in the first 160. When the grouping into three sets of three each is impeded by the fact that two responses are equally frequent, one group is made to include 4 and the other, 2. We have tabulated the responses for the first, second, and last 160, for twenty-one more individuals taken at random from those not used in the eighteen. The results for each of the thirty-nine individuals are shown in Table 58.

The three connections of greatest frequency in the first 160 are not necessarily the three connections of greatest strength in the individual mind concerned, there being a certain amount of error in determining relative strength by only 160 appearances. The same holds true of the three connections of least frequency in the first 160 as representa-

tives of the three connections of least strength. Part of the loss of the most frequent and gain of the least frequent would evaporate if we had accurate measures of the three strongest connections and three weakest connections. The error is, however, small. It is inoperative upon the difference between our records for the second and later 160's. These show clearly that the three favorite numbers do not grow more favored, although their early strength is relatively over twice that of the three least favored.

The data from Experiment 24 with the six subjects who had 3840 repetitions each show the same general fact.

TABLE 59

THE FREQUENCIES IN VARIOUS 160'S OF THE RESPONSES WHICH WERE THE THREE MOST FREQUENT AND THE THREE LEAST FREQUENT IN THE FIRST 160 OF EXPERIMENT 24

Individual	Frequency of the Three Highest in the First 160								Frequency of the Three Lowest in the First 160							
	1	2	3	4	21	22	23	24	1	2	3	4	21	22	23	24
C	65	59	72	61	53	56	52	55	33	27	26	38	53	56	39	48
M	79	96	76	68	50	35	44	43	27	21	27	28	43	58	40	47
P	76	74	55	59	63	49	70	78	25	28	34	38	36	34	31	34
R	79	60	63	65	56	58	60	45	18	27	28	30	30	31	37	27
S	81	80	59	62	84	78	79	71	21	31	27	31	31	40	43	50
W	69	69	68	67	62	62	58	64	26	30	27	27	33	31	64	57
Total	449	438	393	382	368	338	363	356	150	164	169	192	226	250	254	263

Table 59 presents the history of the three responses which in the first 160 were of greatest frequency, and of the three which were then of least frequency, in the first four and last four 160's of the twenty-four.

Experiment 28

Eight individuals were instructed as follows:

> I shall read a very long series of nonsense syllables each followed by a number from 0 to 9, like this, *ish 4, vag 3, faz 0,* and so on. Listen to the series in a uniform manner, just letting each pair, a syllable and its number, make its impression. Just passively listen.

A series containing the pairs of Table 60, with the frequencies shown there, was then read. Call this reading the *original presentation.* (These pairs were read at the rate

of one every two seconds in an order that was random except that no pair was repeated within twenty successive pairs.)

TABLE 60

NONSENSE SYLLABLE AND NUMBER PAIRS

Pair	Number of Times Read	Pair	Number of Times Read	Pair	Number of Times Read	Pair	Number of Times Read
mi 7	8	fu 5	4	ul 2	4	te 5	4
" 6	4	" 4	2	" 0	2	" 0	2
" 8	4	" 6	2	" 5	2	" 9	2
" 5	2	" 3	1	" 6	1	" 1	1
" 9	2	" 7	1	" 7	1	" 2	1
dek 3	8	la 6	4	om 8	4	fum 4	4
" 2	4	" 5	2	" 1	2	" 2	2
" 4	4	" 7	2	" 9	2	" 7	2
" 1	2	" 4	1	" 0	1	" 5	1
" 5	2	" 8	1	" 5	1	" 6	1
bil 9	8	le 7	4	si 8	4	duz 0	4
" 0	4	" 6	2	" 4	2	" 3	2
" 1	4	" 8	2	" 7	2	" 9	2
" 2	2	" 5	1	" 1	1	" 2	1
" 8	2	" 9	1	" 6	1	" 7	1
ko 8	8	mo 6	4	wa 1	4		
" 0	4	" 5	2	" 0	2	and about fifty miscellaneous pairs read once or more	
" 9	4	" 7	2	" 4	2		
" 3	2	" 4	1	" 2	1		
" 6	2	" 8	1	" 6	1		
bo 2	4	rok 1	4	foz 8	4		
" 1	2	" 2	2	" 7	2		
" 3	2	" 3	2	" 9	2		
" 0	1	" 4	1	" 3	1		
" 4	1	" 5	1	" 6	1		
da 3	4	raz 0	4	ral 0	4		
" 2	2	" 1	2	" 4	2		
" 4	2	" 2	2	" 7	2		
" 1	1	" 3	1	" 3	1		
" 5	1	" 4	1	" 9	1		
fi 4	4	id 6	4	kel 1	4		
" 3	2	" 3	2	" 2	2		
" 5	2	" 7	2	" 5	2		
" 1	1	" 4	1	" 4	1		
" 6	1	" 5	1	" 7	1		

After the pairs had been read, the subjects were told, "I shall now read the syllables which you have heard, one

every five seconds, and you will write down for each, a number from 0 to 9. Write the first number that comes to your mind. If no number comes to your mind, write any number from 0 to 9." Thirty-two hundred syllables were then read in ten sittings, 320 per sitting, including 40 of each syllable of the 24 pairs listed above. During the first seven sittings they were read at the rate of one every five seconds: during the last three sittings, at the rate of one every two and a half seconds.

We then studied the last twenty responses of each of the eight individuals to *mi*, *dek*, *bil*, *ko*, *bo*, *da*, *fi*, and the other syllables, each of which had been put in connection with five different numbers, 8, 4, 4, 2, and 2 times, respectively, or 4, 2, 2, 1, and 1 times, respectively. The problem was, of course, to measure the extent to which those connections which had the impetus of 8 or 4 repetitions gained during the experiment at the expense of those which had only 2; and similarly for the cases of 4 or 2 repetitions as against 1.

The responses which had been connected with a situation 8, 4, or 2 times, respectively, appeared 210, 33, and 177 times, respectively, out of 640, there being 220 responses which had not been connected at all with the given situation in the original presentation to the subjects. The responses which had been connected with a situation 4 times, 2 times, or once, respectively, appeared 549, 786, and 638 times, respectively, out of 3200, there being 1227 occurrences out of 3200 connections which did not appear at all in the original presentation.

Consider first the cases of 4, 2, 2, 1, and 1. In order to separate (*a*) the influence of the relative number of repetitions in the original presentation from (*b*) the influence of all other factors, we may calculate what would have been the results by various hypotheses about (*a*), allowing as much influence to (*b*) as will produce approximately 1227 occurrences of connections which did not appear at all in the original presentation.

As the first hypothesis (Hypothesis I), assume that a connection which appears twice as often in the original presentation will, by the time the last twenty responses are made, add to itself 25 percent of the frequency of any connection made only half as often in the original presentation, and a connection which appears four times as often as another in the original will add to itself 50 percent of the frequency of that other connection. Then the 4, 2, 2, 1, 1 series should become 6, 2, 2, 0, 0. For the 4 gains 0.5 from each of the 2's, and 0.5 from each of the 1's. Each 2 will remain 2, gaining 0.25 from each of the 1's, and losing 0.5 to the 4. Each 1 will become 0, by losing 0.5 to the 4 and 0.25 to each of the 2's. Thirty-two hundred cases should appear as 1920 cases of the "four times as often," 1280 (640 + 640) cases of the "twice as often" and 0 (0 + 0) cases of the other. By giving all other influences than that of the original presentation a weight of three to its one we should have 720, 800 (400 + 400), 480 (240 + 240), and 1200,* in place of the 549, 786, 638 and 1227 actually found. It is obvious that Hypothesis I strengthens the frequent much more than the facts show.

By Hypothesis II, we assume that there is zero strengthening of the strong at the expense of the weak. Then the influence of the original presentation should produce responses in the last 20 for each person as follows: 1280 cases of those presented 4 times as often, 1280 cases of those presented twice as often, and 640 cases of those presented once. By giving all other influences than that of the original presentation a weight of three to its one we have 560, 800, 640, and 1200† in place of the 549, 786, 638, and 1227 actually found.

*Influence of original	1920	640 + 640	0 + 0	0
Influence of all other factors (×3)	960	960 + 960	960 + 960	4800
Sum divided by 4	720	400 + 400	240 + 240	1200

†Influence of original	1280	640 + 640	320 + 320	0
Influence of all other factors (×3)	960	960 + 960	960 + 960	4800
Sum divided by 4	560	400 + 400	320 + 320	1200

This is a very close correspondence. If we make the weight attached to all other factors 3.28+, so as to produce 1227 for the cases of zero occurrence in the original, we have 544, 789, 640, and 1227, which differ from the 549, 786, 638, and 1227 actually found, by only —5, +3, +2, and 0.

If this same treatment is applied to the 8, 4, 4, 2, 2 presentations, the results are not clear. At their face value they show the 8's and 2's both gaining at the expense of the 4's.

Hypothesis I, using weights of 1 and 2.2 for the original presentation and for all other forces than it, gives 164, 168, 88, and 220, instead of the 210, 33, 177, 220 actually obtained. Hypothesis II, with the same weights, gives 124, 168, 128, and 220. Neither hypothesis produces results at all like those actually obtained, one being about as much in error as the other. More than four syllables are required to produce consistent results.

As a check upon this conclusion we may consider the occurrences in the first ten of the responses to each of the twenty-four syllables of the experiment.

In the case of the 4, 2, 2, 1, 1 series, the frequencies were 274, 355, 332, and 639 for the numbers which had been connected with the syllable in question 4, 2, 1, and 0 times, respectively. Hypothesis I does not fit these results at all well. Hypothesis II fits them fairly closely. Using weights of 1 for the original presentation and 4 for all other factors, we have 256, 384, 320 and 640, differing by —18, +29, —16, and +1 from the obtained results. Hypothesis I with the same weights gives differences of +46, +29, —76 and +1.

In the case of the 8, 4, 4, 2, 2 series, the frequencies were 104, 29, 94, and 93 for the numbers which had been connected with the syllable in question 8, 4, 2, and 0 times, respectively. Both the 8's and the 2's seem to gain at the expense of the 4's. More syllables are needed.

On the whole, considering both the last twenty and the

first ten responses to each of the four syllables, the evidence is strongly to the effect that the strong do not gain at the expense of the weak.

This second division of Experiment 28 is somewhat like the classic experiment of Calkins ['94, pp. 477 to 479]. Her results also show no waxing of the strong at the expense of the weak. She found that when a color was connected with one two-place number once and with another two-place number twice or three times within a series of twelve pairs, the color when presented later called up the twice or thrice connected number somewhat less than twice or thrice as often as it did the number which had been connected with the color only once.

We have found no other experiments concerning the influence of repetition which are suitable for extending or criticizing the results reported here.

§ 6. Summary of results concerning the effect of repetition of a situation upon the connections leading from that situation

This section needs hardly more than a sentence. We have devised experiments in which frequent connections compete with rare connections, and strong connections compete with weak. The results as a whole, and with substantial uniformity, prove that with repetitions of a situation the frequent and strong connections gain very, very little, if at all, from the weak. The most reasonable explanation of them is that the gain is zero. Against any one of our experiments by itself alone certain objections can be made, by believers in some theory of "drainage," and by disbelievers in the potency of effect, but some other of the experiments will be found free from that objection.

All psychological and educational doctrines which rely upon experience as such, in disregard of its consequences, are now less acceptable than ever. If a certain state of affairs acts upon a man a thousand times a week for a year, he will, so far as the mere repetition of that state of affairs

is concerned, probably respond no better the last week than the first.

The repetition of a situation does, of course, cause increased familiarity with it and perhaps a changed emotional attitude toward it, as in relief from strains and pressures felt at first, or in increased self-confidence. We must, however, be careful to keep separate the changes in attitude and emotion due to the sheer repetition in and of itself, and those due to after-effects which, in the case of connections with emotional responses, it may be impossible to conceal from the subject.

CHAPTER III

THE INFLUENCE OF THE REPETITION OF A CONNECTION WITHOUT BELONGING

WE HAVE shown that the mere repetition of a situation is, in and of itself, unproductive for learning. It has no useful selective power; it causes no adaptive changes. The mind under the influence of such repetition may sometimes suffer certain limitations in its responses, but what they will be is fortuitous and unpredictable. In general, repetition of a situation in and of itself simply maintains the *status quo*, whatever it may be. In particular, the more frequent connections will not wax and the less frequent wane.

With the repetition of a *connection*, meaning thereby a situation and a given response to it, the case is different. If, by some arrangement of the individual or the environment or both, the individual is caused to vary from his initial tendencies to respond (by, say, A, B, C, D, E, F, G, H, and I with relative frequencies of 3, 6, 10, 16, 30, 16, 10, 6, and 3) in the direction of repeating one same response (say A) a hundred times, making a hundred occurrences of $S \longrightarrow A$, this experience will in and of itself strengthen $S \longrightarrow A$ relatively to $S \longrightarrow B$, $S \longrightarrow C$, etc. Experiments soon to be described will demonstrate this.

Belief in some such potency of repetition has been almost universal in psychology, but the evidence to prove it has been somewhat unsatisfactory. In most cases there have been not only repetitions of the connection, but also certain after-effects of a more or less satisfying nature. The connections learned by repetition have usually been such as were right and proper. I have tried to discover what happens when we keep the influence of frequency of occurrence

of the connection free from any chance for such satisfying after-effects to operate.

The orthodox view of the potency of repetition of a connection has recently been attacked by various adherents to Gestalt principles, who would limit the efficacy of repetition to cases where the things connected possessed some inherent unity or *Zugehörigkeit.* It has also been attacked on the basis of experimental findings, especially by Lewin, who found that two hundred or more repetitions of nonsense syllables in a certain sequence left only a very weak tendency for one of them to call up its sequent. Our experiments will, I hope, clear up these disagreements.

The first to be described concern the coöperation of temporal sequence and what I shall call "belonging."

The term mental connection has meant different things to different psychologists and at different times. One clear-cut and important possible meaning is mere sequence in time of two events in the mind, or in a man's behavior. And we shall first study the influence of repetition of a temporal sequence of events in the mind, though perhaps no psychologist ever meant only such temporal sequence when he wrote of "association by contiguity" or of "the mere association" or of "one event going with another in the mind," or of "a certain response being connected with a certain situation."

If two events, A and B, occur in the mind in that sequence with nothing but a very brief interval of time as an interruption, and do so repeatedly, what results which would not have resulted if they had both occurred, but days apart with an infinitude of interrupting events? In particular, what results in respect of the probability that A thereafter will evoke B?

The answer to which the evidence (with one very important possible exception) points is that such mere sequence does little or nothing in and of itself. Ten or twenty or a hundred such repetitions of B after A do not appreciably increase the probability that A will evoke B.

Experiment 29

Consider the following experiment: The paragraph printed below is read ten times to persons who are instructed to "listen to what I read with moderate attention, as you would listen to a lecture."

Belonging A

Alfred Dukes and his sister worked sadly. Edward Davis and his brother argued rarely. Francis Bragg and his cousin played hard. Barney Croft and his father watched earnestly. Lincoln Blake and his uncle listened gladly. Jackson Craig and his son struggle often. Charlotte Dean and her friend studied easily. Mary Borah and her companion complained dully. Norman Foster and his mother bought much. Alice Hanson and her teacher came yesterday.

As soon as the tenth reading is completed the subjects of the experiment are required to answer the following questions, ten seconds being allowed for answering each one of them.

1. What word came next after rarely?
2. " " " " " Lincoln?
3. " " " " " gladly?
4. " " " " " dully?
5. " " " " " Mary?
6. " " " " " earnestly?
7. " " " " " Norman Foster and his mother?
8. " " " " " and his son struggle often?

Questions 1, 3, 4, 6, and 8 test the influence of ten moderately attentive repetitions of a sequence with very, very little belongingness. Questions 2 and 5 test the influence of ten such with the belongingness which attaches to the first and last name of the same person. Question 7 tests the influence of ten such with the belonging which attaches to the subject and predicate in a sentence.

Two series of experiments were carried out with 100 and 140 subjects, respectively. The frequency of right responses to questions 1, 3, 4, and 6 testing the strength of the

connection between the last word of one and the first word of the next, was 2¾ percent in one series of experiments and 2¼ percent in another. The percentages should be as high as these by mere chance guessing of some first name of the ten heard. The frequency of right responses to questions 2 and 5, testing the strength of the connection between first and last name was 21½ percent in one series of experiments and 19½ in another. These rise to 81 and 73 for question 7. The connection between "and his son struggle often" and the immediately following "Charlotte" was not strengthened at all by the ten occurrences of the sequence. The percent of correct responses was 2 for one series and 1 for the other. Guessing at random would produce as high percents as these.

Consider the following experiment in which the same general issue is studied but with different material and with a change in the instructions designed to equalize attentiveness throughout by a method different from that of the previous experiment.

Experiment 30

The series of sentences shown below under *Belonging B* was read six times to 200 college and university students. They were instructed as follows: "Please listen to what I read just attentively enough so that you can say that you have heard it and understood it." As soon as the sixth reading was completed the subjects were asked to write answers to the questions listed below which were read at the rate of one every ten seconds in the order shown here.

Questions 1 to 4 test the strength of the connection from the end of the one sentence to the beginning of the next. Each of these had a frequency of 6 but with very little belonging—only so much as would be due to the few persons who may have considered the series of sentences as something to be memorized as a total. With a possibility of 800 correct responses there were only 5, or 6 tenths of one percent. This number may be accounted for by mere

guessing of any given name remembered as having been heard, or even by mere guessing of any common given name.

Questions 21 to 24 test the strength of the connections from verb to adverb in the same sentence. Each verb was followed six times by each of four adverbs. The two terms belonged together closely. With a possibility of 3200 correct responses (if each subject had written four for each question) there were 265 or 8.3 percent. Guessing from adverbs remembered would give only 80 plus or minus a small chance variation, even if each subject wrote 16 words. As a matter of fact, few of the subjects wrote more than half that number, so that 30 is a generous allowance.

A less extreme contrast between little and much belonging is given by questions 5 to 8 and questions 9 to 12. In the former, there were 24 occurrences for each of the four connections, but the degree of belonging was only that due to inclusion of the two names in the same sentence. In the latter there were only six occurrences of each connection but the belonging was of first and last name of the same person in the same sentence. The correct responses numbered 55 for the former and 94 for the latter. With only a fourth as many repetitions the greater belongingness results in much greater strengthening, producing nearly twice as many correct responses. In both of these comparisons position in the test series favors the connections with less belonging.

Belonging B

Alfred	Duke	and	Ronald	Barnard	worked	sadly.
Edward	"	"	"	Foster	"	lightly.
Francis	"	"	"	Hanson	"	here.
Barney	"	"	"	Curtis	"	today.

Lincoln	Davis	and	Spencer	Lamson	argued	rarely.
Jackson	"	"	"	Evans	"	singly.
Charlotte	"	"	"	Landis	"	yesterday.
Mary	"	"	"	Noble	"	slowly.

Norman	Bragg	and	Truman	Astor	played	hard.
Alice	"	"	"	Dennis	"	gently.
Daniel	"	"	"	Mason	"	there.
Janet	"	"	"	Napier	"	apart.

Martha	Croft	and	Roscoe	Bentley	watched	earnestly.
Norah	"	"	"	Hunter	"	brightly.
Andrew	"	"	"	Podson	"	much.
Ellen	"	"	"	Conant	"	late.

Kenneth	Blake	and	Thomas	Rollins	listened	gladly.
Orville	"	"	"	Durant	"	everywhere.
Arthur	"	"	"	Roper	"	then.
Henry	"	"	"	Nichols	"	long.

Maxwell	Craig	and	Richard	Allen	struggled	often.
David	"	"	"	Franklin	"	up.
Laura	"	"	"	Travis	"	always.
Patrick	"	"	"	Custer	"	quickly.

Bertram	Dean	and	Vincent	Ellis	studied	easily.
Norris	"	"	"	Golden	"	fiercely.
Horace	"	"	"	Wilder	"	little.
Lewis	"	"	"	Sackett	"	easily.

Peter	Borah	and	Sarah	Alden	complained	dully.
Edgar	"	"	"	Hogan	"	never.
Rachel	"	"	"	Morris	"	now.
Randolph	"	"	"	Bishop	"	together.

1. What word came next after rarely?
2. " " " " " much?
3. " " " " " up?
4. " " " " " fiercely?
5. " " " " " Blake and?
6. " " " " " Borah and?
7. " " " " " Bragg and?
8. " " " " " Craig and?
9. " " " " " Alfred?
10. " " " " " Bertram?
11. " " " " " Kenneth?
12. " " " " " Lincoln?
13. " " " " " Astor?
14. " " " " " Allen?
15. " " " " " Alden?
16. " " " " " Barnard?

17. What word or words came after Richard?
18. " " " " " " Ronald?
19. " " " " " " Roscoe?
20. " " " " " " Sarah?
21. " " " " " " argued?
22. " " " " " " complained?
23. " " " " " " listened?
24. " " " " " " played?

Experiment 31

A more conclusive experiment may be arranged as follows: Let a long series of pairs of words followed by numbers be arranged in which also certain of the numbers are always followed by certain of the words. We announced to the subjects "I shall read you a long list of pairs of words and numbers like *bread 29*, *wall 16*, *Texas 78*. You will listen as I read them. Pay about as close attention as you would in an average class. Be sure that you hear each pair as I read it." The series of 1304 pairs contained, among other pairs, four pairs (*dregs 91*, *charade 17*, *swing 62*, and *antelope 35*) each occurring 24 times, and so placed that *dregs* always came just after *42*, *charade* always came just after *86*, *swing* always came just after *94*, and *antelope* always came just after *97*.

After the series had been read, the subjects were asked to write which numbers came just after certain words and also which words came just after certain numbers, namely, *42*, *86*, *94*, *97*.

The average percentage of correct responses for the numbers following words in pairs occurring 18 or 21 times each scattered throughout the series was 37½ (median 38). The average percentage of correct responses for the words following the numbers 24 times each was one half of one percent, which is no more than mere chance guessing would give.

The nature of the instructions, the way in which the pairs were read and the habits of life in general, led the subjects to consider each word as belonging to the number that fol-

lowed it, and each number as belonging to the word that preceded it. In this experiment, the temporal contiguity of a number with the word following it, the mere sequence without belonging, does nothing to the connection.

It may be objected that the attentiveness to the *word*⟶*number* connections inhibits or counteracts a real tendency of the connections from a number to a sequent word to be strengthened by sheer temporal contiguity. But this does not seem to be true. At least, any such tendency is very slight. For if we reduce this alleged inhibition by reducing the attentiveness to the series, we have the same result as before. If, instead of encouraging an attentive and studious attitude to such a series, we instruct subjects: "Do not give any closer attention than is required for you to keep awake and hear the words and numbers," the percentages correct in a second hundred subjects for the *number*⟶*word following* pairs are still only what would be attained by chance.

In another somewhat similar experiment with a sequence which was repeated 48 times all fourteen persons so tested failed.

Experiments of the same general nature as these can be devised to measure the influence of sequence plus varying amounts of belongingness from little to much. They will corroborate our finding that mere sequence with zero belongingness has approximately zero influence in strengthening a connection.

It is presumably in part the lack of belonging of one syllable to the others which explains the failure of Van der Veldt to know the order of twelve nonsense syllables which he had heard read aloud in that order 2490 times, in his experiments ['28, p. 32]. The subject read one and then made a certain movement corresponding to it, then read another and made another movement corresponding to that, and so on. Each syllable was thus like an imperative sentence by itself. It and a movement belonged together,

but it did not belong with the preceding or following syllable.*

The belonging which is always or nearly always necessary in order that the repeated occurrence of a sequence may strengthen the connection between the first term of the sequence and the second need not be more than the least which the word implies. There need be nothing logical, or essential, or inherent, or unifying in it. Any "this goes with that" will suffice. Each nonsense syllable in a series which is read as a series "belongs" to the one before it in the series. 1492 belongs to Mr. Jones as his telephone number as truly as to Christopher Columbus as an auspicious year. In an experiment, 1492 may truly belong to 65 or 7843, or sig nop.†

A very small degree of belonging may increase under suitable conditions. For example, cats learned to scratch or lick themselves when confined in certain cages. The door was pulled open by a string as soon as the animal performed the specified act. At the beginning there was presumably only a very low degree of belonging between the impulse to scratch and the situation of being confined in that cage (or in any cage), the act of scratching belonging chiefly to some bodily stimuli. This low degree of belonging was indeed probably one main reason why the learning of so simple a connection was so slow. At the end of the training it was probably much closer. If the experimenter had then set the requirement that the cat must scratch its left side, that would probably have been then learned more

* Van der Veldt himself uses the fact to illustrate the importance of the desire to make the connection or at least of the interest in the series.

† It may be noted here that the results obtained by Henning, Kuhn, Lewin, Van der Veldt, and others are for the influence of sequence plus belonging, as the term is used here. The repetitions used by them should have strengthened the connections. And they did. What Lewin's results really show, for example, is not that repetition of a series of nonsense syllables adds zero strength to the tendency of one of them to evoke its sequent, given the total situation as it was, but that when the total situation is mutilated by changing the mind's set or adjustment, the response will change. Suitable attention will be paid later to all the important criticisms of the potency of repetition.

readily than if it had been the requirement at the beginning.

The principle of belonging is of great importance. It has been neglected by psychologists, perhaps because we have taken it for granted.

It is of special importance in cases where the event A consists of several parts (say, A_1, A_2 and A_3), and event B which follows A repeatedly becomes connected with one of these with which it "belongs" but not with the others; or where event B consists of several parts only one of which (that which belongs with A) becomes connected with A by repetition of the $A \longrightarrow B$ sequence; or where both A and B consist of several parts and where the repeated sequence strengthens the connection from one part of A to one part of B which belongs with that part of A, but leaves the other possible connections nearly or quite unchanged.

Experiment 32

Consider, for example, this experiment. The experimenter instructs the subjects as follows: "I shall show you cards with nonsense words (showing one), and say English words, always saying the same word for the same card. Look and listen with moderate attention, but do not repeat to yourselves the nonsense words that you see or the English words that you hear. And do not try to think what the English word will be in any case. Simply look and listen."

The series consisted of 24 cards, 6 of which were 12 inches long, 6 were 14 inches long, 6 were 16 inches long, and 6 were 18 inches long. The English words for the 12-inch cards were all conjunctions (*if, whenever, therefore, and, however,* and *because*). Those for the 14-inch cards were all nouns (*house, ministry, summer, street, afternoon,* and *picture*). Those for the 16-inch cards were all verbs (*drink, elevate, become, speak, remember,* and *remain*). Those for the 18-inch cards were all adjectives (*sweet, abundant, stupid, cold, beautiful,* and *pleasant*). The cards were held at one of three heights above the desk (approximately 1 foot, 2 feet, or 3 feet). When the card

was held three feet up the English word was one having one syllable only (*if, and, house,* etc.). When it was held two feet up the English word had three syllables (*whenever, however, ministry,* etc.). When it was held one foot up the English word had two syllables.

If the series is repeated three times we have frequencies of 3 for each nonsense word$\longrightarrow$English, 18 each for short card$\longrightarrow$conjunction, very long card$\longrightarrow$adjective, etc., and frequencies of 24 each for held high up$\longrightarrow$one syllable, held low down$\longrightarrow$two syllables. But under the conditions of the experiment and its directions the nonsense words on the card and the English words are attended to and felt to belong together, whereas the length of the card and the grammatical class of the word, whether or not they are attended to, do not belong together. This is also true of the position at which the card is held and of the number of syllables in the English word. The 18 repetitions will not raise the percentage of correct responses to "What part of speech were the English words for the short card like this (showing a 12-inch card)? Was it a noun, verb, adjective, or conjunction?" much above chance. Nor will the 24 repetitions of the connection between a certain position of the card and a certain number of syllables in the English word. Three repetitions of the connections between the nonsense words and the English words which belonged to them will strengthen these connections far more. In one group of educated adults, for example, the number of these correct in the test was 55 per hundred, where chance would have given less than 5 per hundred. The percent of correct responses to the questions about parts of speech was 31 or 6 more than chance would have given. The percent of correct responses to the questions about number of syllables was 42 or 9 more than chance would have given. In a second group the corresponding percents were 55, 32, and 44 or 50, 7, and 11 above chance. The strengthening per repetition with close belonging is forty to fifty times that with slight belonging.

The results of such experiments cannot be dismissed as matters of insufficient attention to the various aspects of the two terms of the sequence. The subjects are aware of the size of the card, the position at which it is held, the grammatical class of the English word spoken, and the number of syllables in it. These features of the two terms of the sequence do produce effects in the neurones. If, after the display of a card, the four sizes or the three positions had been shown and the subjects asked which was its size and position, there would have been more than 25 percent and 33 1/3 percent of right responses. In a certain sense they are even attentive to these features of the two terms. But they are not aware of the grammatical class of the English word or of the number of syllables in it *as belonging to* or *due to* the size and position of the card. They do not attend to these connections as they do to the connection between nonsense word and English word. Attentiveness to various features of two terms as mutually belonging will strengthen the connection more than inattentiveness, of course. But attentiveness to these features, no matter how vigorous, will do little or nothing to strengthen a connection between them, unless it includes attentiveness to them *as belonging.*

Mere sequence in time does very little in and of itself. It is of importance rather as a condition for the operation of other forces.

Statements concerning the potency of repetition which assert or assume that the mere temporal sequence of two events in the same mind acts to strengthen the connection between them may properly be critcized. Our statement, it will be remembered, was more restricted.

Responses are made *to* situations or elements of situations; they do not simply follow *after* them. If a boy in school for a year always sneezed .2 sec. after he was confronted by $9 \times 8 = ?$, and never got the 72 until .4 sec. after, he would none the less thereafter respond to $9 \times 8 = ?$ by 72 rather than by sneezing.

In the compound responses to compound situations which make up much of human behavior, though the time interval may be the same between the A, B, C, D, and E which compose the situation S and the 1, 2, 3, 4, 5 which compose R, 1 may none the less be connected strongly with D, 2 with A, and 3 with C, if 1, 2, and 3 "belong with" or "are responses to" D, A, and C, respectively.

The concept of serial belonging or "this goes with that" can be made more definite in either of two ways: we may list and itemize the cases of it or we may specify its physiological basis. There would probably be no serious disagreements in such a list, except perhaps about certain marginal cases where the belonging is weak or inconstant or evanescent. As to the physiological basis of belonging, there are at present no hypotheses to disagree about. The one which I offer is the very simple one that belonging is the consequence of direct continuity in conduction. When neurones a, b, c, etc., or neurone patterns 1 and 2, conduct directly into neurones α, β, γ, etc., or neurone patterns I and II, there is belonging. Otherwise there is not. The more fully all of a, b, c, etc., or 1, 2, etc., conduct into α, β, γ, etc., or I, II, etc., and into no other neurones or neurone patterns, the greater is the belonging.

If during the same length of time all of D, E, F conducts into $o\ \pi\ \rho$ and into naught else, and all of M, N, O conducts into $\delta\ \zeta\ \eta$ and into naught else, $o\ \pi\ \rho$ will belong with D, E, F and by repetition become connected with it, and $\delta\ \zeta\ \eta$ will belong with M, N, O and become connected with it, but the simultaneity of $o\ \pi\ \rho$ and $\delta\ \zeta\ \eta$ will not connect them, and the succession of D, E, F and $\delta\ \zeta\ \eta$ will not connect them.

There is one curious and important possible exception to the general evidence that mere sequence in the mind in and of itself is very weak and perhaps totally impotent. This possible exception is the so-called conditioning of reflexes reported first by Pavlov and elaborately studied by his pupils and others, where the act of secreting by the salivary gland of a dog forms a strong connection with the

ringing of a bell or the rotating of a disc or the appearance of a black square which repeatedly precedes and overlaps the act of secreting, though presumably the dog feels no fitness or belonging of that act with that situation, and does not produce or control the act, or pay attention to it, or even, perhaps, know that the secreting is taking place.

The work of Pavlov, Bechterev and their followers will receive special attention later.* The learning seems to be unlike other learning in several ways. For the present we may leave it as an apparent contradiction of the general evidence that mere temporal contiguity of two events in the mind has little power, perhaps no power, to form a connection between them.

We may now turn to our main series of experiments on the influence of the repetition of a connection.

* In Chapter XVI and Appendix X.

CHAPTER IV

The Influence of the Repetition of a Connection with Belonging

§ 1. The problem

In the ordinary experiments upon learning the individual knows what he is to learn. He is consequently satisfied by what makes, or seems to make, progress toward it. It is then difficult to obtain any measurements of the potency of repetition alone. In memorizing lists or pairs, for example, the subject is better satisfied when he holds the material in mind for a second or so after hearing or seeing it than when he loses it. If, on hearing the first member of a pair, he anticipates the second member, he is notably satisfied when his anticipatory reaction is correct. So "number of repetitions" in the ordinary experiments means in part also "number of opportunities for satisfying or annoying after-effects to operate."

We have sought to obtain closer approximations to the activity of repetition plus belonging without the influence of the consequences of the connection, by using a different form of presentation of the connected pairs, by instructing the subjects in certain ways, and by concealing or disguising the learning which we later test.

The most usual plan of our experiments to this end is to present long series of pairs (from about 500 to 4000) in which certain pairs recur often, with instructions to the subjects to listen comfortably without any effort to remember and without thinking about what is heard, just experiencing what is provided.* A second plan is to have

* Psychologists in general have been very reluctant to admit that the satisfying after-effects of a connection work back upon it to strengthen it. I shall later present direct evidence that they do. In the present connection it

the subjects copy the pairs or write them from dictation, the experiment being described as a means of obtaining data on fatigue, or on speed and accuracy, or on lapses.

In some of the experiments we asked the following questions at the close of the test:

1. Did you, when some of the words were read, try to anticipate the number, that is to judge or guess what it would be before it was said?
2. If so, in what percent of the cases did you do so?
3. Did you feel more pleased when you guessed right than when you guessed wrong?

In one experiment in which the individuals were requested to pay about as close attention as to an ordinary lecture, over nine-tenths replied "Yes" to No. 1. Their median percent was 33 1/3. All those who answered No. 3, said "Yes." A few did not answer it, probably by inadvertence.

In these experiments the repetition is not of the connection between a situation and a response to that situation in the strict sense, but rather of connection patterns of the form (1) presentation of A⟶ (2) perception of A (probably often followed by (2*a*) the production of an equivalent of A in inner speech) and (3) presentation of B⟶ (4) perception of B (probably even oftener followed by (4*a*) the production of an equivalent of B in inner speech). The detailed facts will be less valuable than if we had had the subjects actually say or write B upon hearing A, but the general facts with which we are concerned will be discovered as well by our procedure, in which the subject's learning may consist in strengthening the connection between

is instructive to note the extreme difficulty of devising arrangements whereby something can be learned without any influence from satisfying after-effects. For example, some persons hearing *elm 46* tend, in spite of the instruction to the contrary, to try to say it over to themselves as soon as they hear it and to feel better if they are able to do so than if they lose part of it. When they do hear *elm* again and for any reason anticipate in mind the same number as its sequent, they may feel notable satisfaction if their anticipation is correct.

the presentation of A and anything which enables him to evoke an idea of B. It lends itself to group-experiments and so is more economical for our purposes.

These experiments were planned to contribute data on problems other than the effect of repetition of a connection plus belonging; and our account of them will consequently be more complicated than would be desirable if they were to be used for only the one problem. We shall first present one experiment in some detail and apply its findings to various problems. Then we shall report the essential facts of the other experiments. Finally, we shall take up one problem after another, using the results from all the experiments.

§ 2. A TYPICAL EXPERIMENT

Experiment 33

A series of 254 different pairs, each consisting of a word, followed by a two-figure number (called hereafter the *adopt series*) was read to 200 adult students at the rate of two seconds per pair. The series consisted of the 100 pairs shown below in the *key to test*, occurring each 3 to 21 times as specified, plus 16 pairs occurring 6 times, 24 pairs occurring 3 times, 42 pairs occurring twice, and 72 pairs occurring once. In general the different occurrences of each pair were scattered fairly evenly through the entire series of 1212, but those recorded as 3s, 6s, 9s, and 12s were repeated as uninterrupted sequences, and 8 of the 16 pairs with six occurrences (not in the key) and 8 of the 24 pairs with three occurrences (not in the key) were given as sequences interrupted by one pair (such as *narrow 75, manly 45, narrow 75, group 53, narrow 75, domain 98, narrow 75, crude 31, narrow 75, proverb 68, narrow 75, neglect 64*). The series was so arranged that each number used occurred approximately equally often.

In this *adopt series* there were inserted 4 other pairs, *dregs 91, charade 17, swing 62*, and *antelope 35*, each oc-

Adopt series: key to test

								Occurrences
1 afford	21	26 merit	73	51 noisy	14	76 brag	93	3
2 bald	42	27 hook	59	52 ledge	62	77 chart	52	6
3 alcove	34	28 mason	25	53 peasant	66	78 candy	36	9
4 also	27	29 elm	46	54 his	55	79 chaos	33	12
5 bag	32	30 group	53	55 image	19	80 camel	37	15
6 adverb	10	31 manly	45	56 proverb	68	81 crude	31	18
7 album	41	32 leafy	23	57 paste	74	82 face	56	21
8 twins	22	33 youth	16	58 thirty	30	83 unlucky	13	3
9 city	95	34 king	71	59 moon	79	84 pick	86	3s
10 dome	50	35 book	43	60 petal	82	85 mixer	73	6s
11 persist	78	36 blond	60	61 mitten	42	86 dogma	11	9s
12 dodge	72	37 bishop	39	62 keg	17	87 perhaps	83	12s
13 love	40	38 caress	95	63 kiss	60	88 hug	84	3
14 vacation	52	39 admired	26	64 riches	69	89 success	78	6
15 dinner	20	40 celery	63	65 beauty	30	90 flowers	81	9
16 dance	35	41 velvet	16	66 turkey	44	91 rubies	67	12
17 pus	14	42 entrails	97	67 slimy	87	92 vomit	21	3
18 greasy	51	43 cancer	54	68 abscess	71	93 dandruff	86	6
19 sore	29	44 fail	43	69 ache	59	94 insane	85	9
20 dirty	24	45 alone	49	70 spider	58	95 snake	76	12
21 equip	34	46 normal	93	71 notify	77	96 fence	86	3
22 curl	15	47 nasal	69	72 outfit	29	97 debt	38	6
23 denote	18	48 rainbow	80	73 remove	87	98 legal	51	9
24 margin	13	49 porter	22	74 rafter	92	99 neutral	65	12
25 marble	61	50 pavement	48	75 radiant	70	100 neglect	64	15

curring 24 times, *dregs* always following the number *42*, *charade* always following *86*, *swing* always following *94*, and *antelope* always following *97*. Half the individuals had been given Instructions A and half, Instructions B.

Instructions A

I shall read you a long series of pairs of words and numbers, like *bread 29*, *wall 16*, *Texas 78*. You will listen as I read them. Do not give any closer attention than is required for you to keep awake and to hear the words and numbers.

Instructions B

The same as A except that the last sentence was "Pay about as close attention as you would in an average class. Be sure that you hear each pair as I read it."

One hundred individuals had Instructions A; one hundred, Instructions B.

Nothing was said about the purpose of the experiment or about the possibility of any test, but presumably the great majority of the individuals expected that some form of test would be given. And doubtless some of those receiving Instructions A gave closer attention than that requested.

After the entire series had been read the subjects of the experiment were instructed as follows: "Take one of the sheets of squared paper which you will find by your seat. Do not write your names on it. We shall keep no record of the result of this experiment for any individual. I shall read some words. As I read each word you will write the number which came after it in the experiment if you remember what it was. If you do not remember what number came after it, write the first number that comes to your mind. If no number comes to your mind, write some two-figure number before I read the next word. Write the numbers in a column beginning with the top square." The words of the 100 pairs listed above were then read in order, one every five seconds.

The subjects were also asked after words 25, 50, 75, and 100 to write answers to these questions:

What *word* came after the number 42? If no word comes to mind, guess.
What " " " " " 86? If " " " " " "
What " " " " " 94? If " " " " " "
What " " " " " 97? If " " " " " "

We may first consider these last four tasks, success in which measures the influence of mere sequence with no belonging. The influence was apparently nil. There were 6 right responses out of the 800, or less than 1 per hundred. These could easily have occurred as a result of guessing one of the 56 words heard twelve times or more.

We may next consider the influence of frequency of occurrence plus belonging. The results for each pair were

as shown in Table 61, the record in each case reading. (N) Number of repetitions. (P) Position in test series. (L) Percent of right responses for the fifty subjects scoring the lowest number of rights for the entire hundred pairs. (M) Percent of right responses for the hundred subjects scoring medium number of rights for the entire hundred pairs. (H) Percent of right responses for the fifty subjects scoring the highest number of rights for the entire hundred pairs. (IL) Percent of right responses for the fifty subjects of the inattentive group scoring the lowest number of rights for the entire hundred pairs. (IH) Percent of right responses for the fifty subjects of the inattentive group scoring the highest number of rights for the entire hundred pairs. (AL) and (AH) mean the same as IL and IH, but for the attentive group. (I) Percent of right responses for the entire inattentive group. (A) Percent of right responses for the entire attentive group. (T) Percent of right responses for the entire group.

The same adopt series but without the *dregs*, *charade*, *swing*, and *antelope* pairs was used with 3 graduate students, who were instructed to copy the series pair by pair as rapidly as they could, and were then tested just as the 200 subjects were. Four other subjects did the same except that by a mistake, they copied 80 pairs twice, which gave each of them three additional repetitions of pair 34 and one extra repetition each of pairs 2, 4, 5, 6, 7, 8, 15, 22, 24, 25, 28, 30, 31, 32, 38, 40, 43, 48, 50, 51, 54, 55, 56, 57, 58, 63, 65, 67, 68, 74, and 75. The experiment was given ostensibly as a test of speed and accuracy in copying.

The total numbers correct for these seven were 3, 5, 6, 8, 12, 13, and 40 per hundred. We may assume that all the individuals except the one scoring 40 attended to the pairs only as much as was necessary to hold them in mind for copying, and so we may fairly regard those persons (52 in number) in the two hundred who had total scores of ten or less as having given only moderate attention to the reading of the pairs and as not having repeated them to themselves

Table 61

Percentages of correct responses for 100 pairs in the *adopt* series

		N	P	L	M	H	IL	IH	AL	AH	I	A	T
afford	21	3	1	8	5	20	8	14	4	22	11	13	12
equip	34	3	21	0	2	8	0	8	2	2	4	2	3
merit	73	3	26	0	1	0	2	0	0	0	1	0	½
normal	93	3	46	1	6	18	2	10	4	16	6	10	8
noisy	14	3	51	4	11	34	2	20	8	28	11	18	14½
notify	77	3	71	4	2	8	2	2	6	6	2	6	4
brag	93	3	76	2	1	4	0	4	4	0	2	2	2
fence	86	3	96	0	1	0	2	0	0	0	1	0	½
city	95	3s	9	4	11	26	6	8	10	30	7	20	13½
king	71	3s	34	2	9	18	4	18	6	10	11	8	9½
moon	79	3s	59	0	4	10	0	4	2	8	2	5	3½
pick	86	3s	84	2	0	2	2	0	0	2	1	1	1
love	40	3	13	24	49	54	28	48	42	58	38	50	44
caress	95	3	38	2	3	8	2	2	6	6	2	6	4
kiss	60	3	63	20	44	54	22	46	42	52	34	47	40½
hug	84	3	88	0	7	26	2	16	4	18	9	11	10
pus	14	3	17	4	9	16	2	16	6	14	9	10	9½
entrails	97	3	42	0	9	20	2	16	6	14	9	10	9½
slimy	87	3	67	0	1	8	0	2	0	8	1	4	2½
vomit	21	3	92	8	16	52	8	26	10	48	17	29	23
bald	42	6	2	2	7	20	0	10	8	18	5	13	9
curl	15	6	22	0	14	50	2	28	10	38	15	24	19½
book	59	6	27	3	4	14	4	2	4	12	3	8	5½
nasal	69	6	47	0	7	20	0	14	2	18	7	10	8½
ledge	62	6	52	2	1	0	2	0	2	0	1	1	1
outwit	29	6	72	0	5	20	2	12	4	12	7	8	7½
chart	52	6	77	0	6	4	2	6	4	4	4	4	4
debt	38	6	97	2	7	10	4	4	2	16	4	9	6½
dome	50	6s	10	10	23	44	12	22	28	38	17	33	25
book	43	6s	35	0	10	18	0	12	8	18	6	13	9½
petal	82	6s	60	8	25	32	12	22	20	36	17	28	22½
mixer	73	6s	85	4	1	2	0	4	2	0	2	1	1½
vacation	52	6	14	8	31	62	12	38	24	58	25	41	33
admired	26	6	39	0	5	16	0	10	4	12	5	8	6½
riches	69	6	64	2	0	12	4	6	0	10	5	5	5
success	78	6	89	4	6	6	4	6	8	4	5	6	5½

TABLE 61 (*Continued*)

		N	P	L	M	H	IL	IH	AL	AH	I	A	T
greasy	51	6	18	0	20	34	0	20	18	36	10	27	18½
cancer	54	6	43	6	16	36	6	20	14	34	13	24	18½
abscess	71	6	68	4	9	2	4	12	0	8	8	4	6
dandruff	86	6	93	2	19	38	8	28	16	26	18	21	19½
alcove	34	9	3	6	14	28	4	14	12	32	9	22	15½
denote	18	9	23	0	7	4	0	10	2	6	5	4	4½
mason	25	9	28	4	19	46	4	24	14	46	14	30	22
rainbow	80	9	48	4	15	48	4	20	14	44	12	29	20½
peasant	66	9	53	0	12	24	0	14	10	24	7	17	12
remove	87	9	73	0	4	2	0	4	2	4	2	3	2½
candy	52	9	78	2	27	62	4	38	24	52	21	38	29½
legal	51	9	98	2	9	32	4	18	4	28	11	16	13½
persist	78	9s	11	8	11	12	12	18	4	8	15	6	10½
blond	60	9s	36	10	41	64	8	46	38	64	27	51	39
mitten	42	9s	61	6	3	10	6	10	2	4	8	3	5½
dogma	11	9s	86	0	10	32	4	8	8	32	6	20	13
dinner	20	9	15	16	54	76	22	54	40	84	38	62	50
celery	63	9	40	4	15	50	4	30	8	42	17	25	21
beauty	30	9	65	4	19	56	6	36	10	46	23	28	25½
flowers	81	9	90	0	7	40	0	20	2	32	10	17	13½
sore	29	9	19	2	8	24	0	18	10	14	9	12	10½
fail	43	9	44	0	15	40	0	20	14	36	10	25	17½
ache	59	9	69	2	0	12	2	0	0	12	1	6	3½
insane	85	9	94	6	27	54	6	32	22	56	19	39	29
also	27	12	4	14	45	76	18	64	30	34	41	32	36½
margin	13	12	24	8	38	68	12	36	32	72	24	52	38
elm	46	12	29	2	13	24	10	26	12	22	18	17	17½
porter	22	12	49	0	16	40	2	24	8	40	13	24	18½
his	55	12	54	0	14	46	2	28	6	38	15	22	18½
rafter	92	12	74	2	2	10	2	4	2	8	3	5	4
chaos	33	12	79	4	21	58	8	38	14	44	23	29	26
neutral	65	12	99	0	10	38	0	22	10	26	11	18	14½
dodge	72	12s	12	8	27	36	18	34	16	32	26	24	25
bishop	39	12s	37	6	6	10	4	10	4	10	7	7	7
keg	17	12s	62	2	15	34	4	22	16	24	13	20	16½
perhaps	83	12s	87	0	14	18	6	12	6	22	9	14	11½
dance	35	12	16	10	35	78	10	52	28	68	31	48	39½
velvet	16	12	41	2	35	80	2	56	24	70	29	47	38
turkey	44	12	66	18	43	82	18	54	32	82	36	57	46½
rubies	67	12	91	2	12	32	4	18	8	28	11	18	14½

TABLE 61 (*Continued*)

		N	P	L	M	H	IL	IH	AL	AH	I	A	T
dirty	24	12	20	22	48	80	30	68	26	74	49	50	49½
alone	49	12	45	4	19	52	4	28	10	52	16	31	23½
spider	58	12	70	2	12	36	2	20	14	26	11	20	15½
snake	76	12	95	4	18	58	6	32	12	48	19	30	24½
bag	32	15	5	10	14	44	10	24	8	38	17	23	20
group	53	15	30	8	16	34	10	26	10	28	18	19	18½
image	19	15	55	8	25	64	10	30	14	68	20	41	30½
camel	37	15	80	10	32	78	12	42	30	68	27	49	38
marble	61	15	25	0	8	28	0	14	6	24	7	15	11
pavement	48	15	50	4	10	32	2	10	8	34	6	21	13½
radiant	70	15	75	4	12	42	4	20	12	34	12	23	17½
neglect	64	15	100	2	0	12	2	2	0	10	2	5	3½
adverb	10	18	6	22	74	90	32	78	62	90	55	76	65½
manly	45	18	31	20	46	92	18	64	46	78	41	62	51½
proverb	68	18	56	8	13	48	14	28	6	34	21	20	20½
crude	31	18	81	0	5	22	0	12	2	18	6	10	8
album	41	21	7	16	33	62	20	44	26	54	32	40	36
leafy	23	21	32	0	32	74	2	42	20	76	22	48	35
paste	75	21	57	0	6	12	4	4	2	14	4	8	6
face	56	21	82	4	29	54	10	34	14	58	22	36	29
twins	22	3m	8	40	73	78	44	72	70	78	58	74	66
youth	16	3m	33	14	37	40	20	28	34	46	24	40	32
thirty	30	3m	58	50	59	86	52	74	54	74	63	64	63½
unlucky	13	3m	83	58	90	90	66	88	82	92	77	87	82
Medians for neutrals, not in sequence													
		3		1½	2	8	2	6	4	4	4	4	4
		6		1	6½	17	2	8	4	12	5	8	6½
		9		2	13	30	4	25	10	39	14½	24½	19½
		12		2	15	43	5	27	11	32	16	21½	18¾
		15		6	13	38	7	22	9	34	14½	21½	18
		18		14	29½	69	16	46	26	56	31	41	36
		21		2	30½	58	7	38	17	56	22½	36½	29½
		15, 18, 21		6	15	46	10	27	11	36	18½	23½	21
Medians for neutrals, in sequence													
		3		2	6½	14	3	6	4	9	4½	6½	5½
		6		6	16½	25	6	17	14	27	11½	20½	16
		9		7	10½	22	7	14	6	20	10½	13	11¾
		12		4	14½	26	5	17	11	23	11	17	14

TABLE 61 (*Continued*)

Medians for connections with pleasant first members

N	L	M	H	IL	IH	AL	AH	I	A	T
3	11	25½	40	12	31	24	35	21½	29½	25½
6	3	5½	12	4	8	6	11	6	8½	7¼
9	4	17	53	5	33	9	44	19	26½	22¾
12	6	35	79	7	53	26	69	30	47½	38¾

Medians for connections with unpleasant first members

N	L	M	H	IL	IH	AL	AH	I	A	T
3	2	9	18	2	16	6	14	9	10	9½
6	3	17½	35	5	20	15	30	12½	22½	17½
9	2	11½	32	1	19	12	25	10	18½	14¼
12	4	18½	55	5	30	13	50	17½	31½	24½

Averages for neutrals, not in sequence

N	L	M	H	IL	IH	AL	AH	I	A	T
3	2.4	3.6	11.5	2.3	7.3	3.5	7.9	4.80	5.70	5.25
6	1.1	6.3	17.3	2.0	9.5	4.5	14.8	5.75	9.65	7.70
9	2.0	13.4	30.8	2.5	17.8	10.3	29.5	10.15	19.90	15.03
12	3.8	19.9	45.0	6.8	30.3	14.3	33.4	18.55	23.85	21.20
15	5.8	14.6	41.8	6.3	21.0	11.0	38.0	13.65	24.50	19.08
18	12.5	34.5	63.0	16.0	43.0	29.0	45.0	29.50	37.00	33.25
21	5.0	25.0	50.2	9.0	31.0	15.5	50.5	20.00	33.00	26.50

Averages for neutrals, in sequence

N	L	M	H	IL	IH	AL	AH	I	A	T
3	2.0	6.0	14.0	3.0	7.5	4.5	12.5	5.25	8.50	6.88
6	5.5	14.8	24.0	6.0	15.0	14.5	23.0	10.50	18.75	14.63
9	6.0	16.3	29.5	7.5	20.5	13.0	27.0	14.00	20.00	17.00
12	4.0	15.5	24.5	8.0	19.5	10.5	22.0	13.75	16.25	15.00

Averages for connections with pleasant first members

N	L	M	H	IL	IH	AL	AH	I	A	T
3	11.5	25.8	35.5	13.5	28.0	23.5	33.5	20.75	28.50	24.63
6	3.5	10.5	24.0	5.0	15.0	9.0	21.0	10.00	15.00	12.50
9	6.0	23.8	55.5	8.0	32.5	14.5	51.0	20.25	32.75	26.50
12	8.0	31.3	68.0	8.5	45.0	23.0	62.0	26.75	42.50	34.63

Averages for connections with unpleasant first members

N	L	M	H	IL	IH	AL	AH	I	A	T
3	3.0	8.8	24.0	3.0	15.0	5.5	21.0	9.00	13.25	11.13
6	3.0	16.0	27.5	4.5	20.0	12.0	26.0	12.25	19.00	15.63
9	2.5	12.5	32.5	2.0	17.5	11.5	29.5	9.75	20.50	15.13
12	8.0	24.3	56.5	10.5	37.0	15.5	50.0	23.75	32.75	28.25

or tried to anticipate the numbers or tried to form meaningful associations between word and number.

In so far as this is true, the results for the lowest fifty of the two hundred with neutral pairs (that is, pairs carrying neither pleasant nor unpleasant suggestions) will represent the influence of the given number of repetitions of a belonging sequence attended to and acceptable but not accompanied or followed by any considerable amount of satisfyingness. They may then be taken as approximate minima below which the influence of repetition plus acceptability and belonging but without satisfying consequences will not fall.

They are well above zero. The averages are 5.7, 12.5, and 5.0 per hundred pairs for 15, 18, and 21 repetitions. After allowing 1.1 for what chance alone would give, we have 4.7, 11.4, and 3.9. For our six subjects who presumably attended to the pairs only so as to copy them, the averages are 3.1, 15.6, and 11.4 per hundred pairs for 15½, 18½, and 21½ repetitions (after the allowance of 1.1 for chance). The median for the 15's, 18's, and 21's together for the fifty lowest of the two hundred individuals is 6, or 4.9 after allowance for chance.

If we use, from the hundred who were instructed to be barely attentive enough to hear the pairs, the half having the lowest total scores, we obtain, as the median percentage correct for the 15's, 18's, and 21's, 10, or 8.9 after allowance for chance.

If we had all the individuals of the two hundred with all the pairs of 15, 18, and 21 occurrences in all the cases where there was no satisfying inner repetition, and no anticipation of the second member upon hearing the first, and no satisfying meaningful association—nothing, that is, save repetition plus belonging plus a mild acceptability—the percentages of correct responses would probably be higher. Either of our two methods of selection cuts out the individuals who are the better learners, and the effect of this probably more than counterbalances the effect of

such meaning and satisfyingness as were attached to some of the connections in spite of the instructions. It seems reasonable to suppose that most of the individuals instructed to maintain the low level of attention would do so.

An influence of repetition plus belonging appears even down to three occurrences. The median percentages correct in the test for the lowest quarter of the two hundred and for the low half of the inattentive hundred were as follows:

12 occurrences,	2	and 5,	or 0.9	and 3.9	over chance
9 "	2	" 4	" 0.9	" 2.9	" "
6 "	1	" 2	" −0.1	" 0.9	" "
3 "	1½	" 2	" 0.4	" 0.9	" "

Three or six occurrences in *immediate sequence* strengthen the connections more than the same number scattered. In the case of 9's or 12's, sequential and scattered are about equally effective. Sequence is more effective for the inattentive than for the attentive hundred. The differences are shown in Table 62.

When the first member of a connection is one with relatively pleasant or unpleasant feeling-tone and associations the effect is much stronger than for a neutral, especially when it is pleasant. The facts are presented in Table 62. *Love 40, kiss 60,* and *vomit 21* with 3 occurrences, respectively, have 44, 40, and 23 percent correct for the entire 200, as against 29 percent for the median for a neutral connection with seven times as many occurrences. Generally accepted psychological principles would lead us to expect a more emphatic impression for these words themselves, but they do not explain why the connections with the neutral and insignificant 40, 60, and 21 are so much strengthened. Indeed any emotional excitement from the words or any revival of past experiences by them would, by these principles, while making the words memorable, distract attention from these sequent numbers.

The results of such an experiment provide other useful

data for studying the principles of learning by observing what sorts of pairs are most easily connected in the mind. The meaningful pairs (*twins 22*, *youth 16*, *thirty 30*, and *unlucky 13*) are useful as a sort of starting point and basis for comparison. We shall later collect a set of pairs very easily learned and a contrasting set of pairs equivalent to them in number of occurrences, position in the test series, etc., but very much less well learned.

Table 62

Comparison of the number of correct responses for neutral connections with scattered occurrences with: (a) neutral connections with sequential occurrences; (b) connections with pleasant first members; and (c) connections with unpleasant first members

Differences which are in favor of the neutral scattered are marked minus.

		Differences between Medians								Differences between Averages						
	N	L	M	H	IL	IH	AL	AH	L	M	H	IL	IH	AL	AH
A	3	0½	4½	6	1	0	0	5	−0.4	2.4	2.5	0.7	0.2	1.0	4.6
	6	5	10	8	4	9	10	15	4 4	8.5	6.7	4.0	5.5	10.0	8.2
	9	5	−2½	−8	3	11	−4	−19	4.0	2.9	−1.3	5.0	2.7	2.7	−2.5
	12	2	0½	−17	0	10	0	−9	0.2	−4.4	−20.5	1.2	−10.8	−3.8	−11.4
B	3	9½	23½	32	10	25	20	31	9.1	22.2	24.0	11 2	20.7	20.0	25.6
	6	2	−1	−5	2	0	2	−1	2.4	4.2	6.7	2.5	5.5	4.5	6.2
	9	2	4	23	1	8	−1	5	4.0	10.4	24.7	5.5	14.7	4.2	21.5
	12	4	20	36	2	26	15	37	4.2	11.4	23.0	1.7	14.7	8.7	28.6
C	3	0½	7	10	0	10	2	10	0.6	5.2	12.5	0.7	7.7	2.0	13.1
	6	2	11	18	3	12	11	18	1.9	9.7	10.2	2.0	10.5	7.5	11.2
	9	0	−1½	2	−3	−6	2	−14	0.5	−0.9	1.7	−0.5	−0.3	1.2	0.0
	12	2	3	12	0	3	2	18	4.2	4.4	11.5	3.7	6.7	1.2	16.6

We shall return to these and other matters concerning learning by repetition and belonging with a minimum of satisfying or annoying after-effects after we have become familiar with the other experiments conducted to this end.

§ 3. Further experiments on the repetition of connections

We have carried out experiments of the same general nature as the above but differing as follows:

Pairs consisting of a three-figure number followed by a two-figure number are used to reduce the possible disturbing effects of the formation of accessory meaningful associations. Pairs consisting of a word and a two-figure number but including many pairs where a word is used a

second time with a different number. The intention was to reduce the temptation to anticipate the number, and also to study the relative difficulty of a uniform connection with one which is one of a pair with the same first term and different second terms. Pairs consisting of a word and a two-figure number but including many pairs with many different numbers following the same word, with many different numbers of repetitions, the variety being so great as presumably to discourage effectually any inclination to anticipate the numbers.

Various methods were used to disguise the fact that tests of learning might be made.

Series *Number Number 3586* consisted of 3586 pairs, each consisting of a three-place and a two-place number. Its constitution was as follows:

8	pairs	occurring	48	times	
8	"	"	42	"	
8	"	"	36	"	
8	"	"	30	"	
8	"	"	24	"	
8	"	"	18	"	
8	"	"	12	"	
8	"	"	6	"	
12	"	"	6	"	in sequences
24	"	"	3	"	

10 meaningful pairs occurring 3 times

There were also pairs in which the same three-figure number was followed in half the cases by one two-figure number and in the other half by a different two-figure number. Of these "doubles" there were 8 with 24 repetitions with one two-figure number and 24 with another, 8 with 21 and 21 repetitions, 8 with 18 and 18, 8 with 15 and 15, 8 with 12 and 12, 8 with 9 and 9, and 8 with 6 and 6. There were four extra pairs making 3586 in all. Except for the 12 sequences mentioned above, the occurrences of any one pair were distributed throughout the list so that any two occurrences of it were separated by at least fifty other pairs.

The second members, that is, the numbers from 10 to 99, did not occur equally often, but with frequencies as shown below.

DISTRIBUTION OF FREQUENCIES IN NUMBER NUMBER 3586, AS READ IN EXPERIMENT 34

Second Digit	First Digit 1	2	3	4	5	6	7	8	9	Total
0	3	3	3	9	6	0	6	0	3	33
1	15	9	9	6	0	0	33	69	6	147
2	36	33	117	171	9	6	39	3	6	420
3	6	54	15	6	96	132	144	21	72	546
4	3	66	12	30	105	156	150	75	27	624
5	6	69	6	6	105	6	51	9	27	285
6	129	144	84	9	6	9	132	6	204	723
7	3	87	69	153	3	48	12	6	15	396
8	12	178	6	18	54	3	18	6	12	307
9	9	27	3	6	6	6	24	6	18	105
Total	222	670	324	414	390	366	609	201	390	3586

Two test blanks were used, one for the three-figure numbers always followed by the same two-figure number, one for the "doubles."

The first 80 three-figure numbers in the test for the singles were arranged in this order (of repetitions) 48, 24, 12, 18, 30, 36, 42, 6, 6 sequences, meaningful 3, 48, 24, 12, 18, etc. Then followed eight of 3s and two meaningful 3s. Except for these 10, pairs with different numbers of repetitions are nearly equally distributed over early and late parts of the test. The 80 three-figure numbers in the test for the doubles were arranged in this order (by repetitions) 24, 24; 12, 12; 6, 6; 9, 9; 15, 15; 18, 18; 21, 21; 24, 24; 12, 12; 6, 6; 9, 9; etc., etc.

Subjects were required to write one number for each in the former and two numbers for each in the latter. As in the series previously described, they were instructed to write the number that had followed the three-figure number if they remembered what it was, otherwise to write the first two-figure number that came to mind.

Experiment 34

Eight college students listened to the entire series, had an hour of rest, then heard it all again and were immediately tested. Four subjects were tested with the singles first, then the doubles, and four with the doubles before the singles. The instructions at the beginning were as follows: "I shall read you a long list of three-place numbers like 726 or 939 and two-place numbers like 68, 21, or 47, in pairs. I shall read, say, four ninety-seven twenty-one, three eighty-five sixty-four, nine thirteen twenty-seven, five eighteen twenty-four. The first number will always be

TABLE 63

RESULTS OF EXPERIMENT 34, WITH SERIES NUMBER NUMBER 3586, READ TWICE TO 8 COLLEGE STUDENTS

Pairs in Which the 3-Place Numbers Always Had the Same Sequent				Pairs in Which the 3-Place Numbers Had Two Sequents			
Number of Pairs	Occurrences	Number Correct	Percent Correct	Number of Pairs	Occurrences	Both Numbers Correct	One Number Correct
8	96	18	28	8+8	48+48	0	14
8	84	13	20	8+8	42+42	0	4
8	72	7	11	8+8	36+36	0	11
8	60	5	8	8+8	30+30	0	9
8	48	9	14	8+8	24+24	0	9
8	36	1	1½	8+8	18+18	0	10
8	24	2	3	8+8	12+12	0	4
8	12	2	3				
8	12 (6 seq.)	8	12½				
8	6	4	6				
Meaningful pairs, such as 111→33, 123→45, 135→79, and 100→99							
10	6	36	45				

a three-figure number, that is, one from 100 to 999. The second number will always be a two-figure number, that is, one from 10 to 99. The same three-place number may or may not be always followed by the same two-place number. You are to listen to the pairs of numbers as I read them, without making any effort to remember them or think about them. Just listen comfortably and with equal attention throughout."

The results appear in Table 63.

Experiment 35

Series *Number Number 3586* was used with fourteen university students in an experiment ostensibly on fatigue. The instructions were as follows:

> I shall read a long series of five-figure numbers like 218 97, 432 16, 874 53. You will write each one as I read it making as clear and legible figures as you can in the time available. Try not to miss any, and have each one correct. I shall read each number in two parts like two eighteen ninety-seven, four thirty-two sixteen, eight seventy-four fifty-three. Write the numbers in columns. Begin a new column when I say "Begin at the top."

The numbers were then read at the rate of 2½ seconds for each three-figure two-figure pair, with a rest of 2 minutes after each 320 pairs, and with rests of ten minutes at the end of 1280 pairs and of 2560.

There was just barely time for some of the subjects to write the numbers.

As soon as the entire series had been read, each individual was given Test Sheet *S* and required to write the two-figure number which came after each three-figure number on sheet *S* and, with it, made the five-figure number written, in case the individual remembered what it was. In case he did not at once remember it, he was required to copy the three-figure number on Sheet *S* and to add to it the first two figures that came to his mind.*

After this had been done he was instructed as follows:

> Mark any that you are sure were right with an *s*.
>
> Answer these questions on the back of the sheet.
>
> 1. Did you make any effort to remember any of the numbers while you were writing them or after you had written them?
>
> 2. Did you form special associations about any of the numbers?

* Test Sheet S is not shown here. It consisted of 90 three-figure members arranged so that pairs of any one sort occurred equally often in the first and last halves of the test.

3. If so, what were they?
4. Write five two-figure numbers which you think occurred very often in the experiment as the last two figures of a five-figure number.
5. Write five two-figure numbers which you think occurred very rarely or never in the experiment as the last two figures of a five-figure number.

All answered "No" to the first question. Twelve answered "No" to the second. The two having special associations noted in one case that in 444 44 all the figures were the same, and in the other that 120 25 had a certain rhythm.

The results for the various pairs arranged according to the number of occurrences of each appear in Table 64.

TABLE 64

RESULTS OF EXPERIMENT 35, WITH SERIES NUMBER NUMBER 3586

Copied once from dictation. 14 university students. Only pairs in which each 3-place number always had the same sequent were used in the test.

Number of Pairs	Occurrences	Number Correct
8	48	10
8	42	3
8	36	5
8	30	5
8	24	2
8	18	0
8	12	1
8	6	0
8	6s	1
8	3	1

and 10 meaningful pairs occurring 3 times each produced 26 correct responses.

Since there were 14 individuals, the expectation by chance is .156 right per pair or 1.24 per eight pairs. This is exceeded by those pairs having 48, 42, 36, and 30 occurrences (the sums correct being 10, 3, 5, and 5, respectively).

Such an experiment measures the force of sheer frequency plus belonging with as near a minimum of satis-

fying after-effect of the connection as is perhaps obtainable. The individuals had no interest in remembering any of the five-figure numbers longer than to write them. If in late learnings of, say, *one twenty* the subject occasionally anticipated the *twenty-five* and found his anticipation correct, the satisfyingness thereof was only such a very mild satisfyingness as perhaps attaches to any exercise of power without thwarting. If, in late hearings of, say, *eight hundred one twenty four*, the subject recognized it as a number that had occurred before, the satisfyingness of such recognition could have been only the very mild satisfyingness of a state of recognition versus ignorance.

In this particular experiment the probability that the 23 correct responses for pairs occurring 30 or more times are largely due to the force of mere frequency plus belonging is increased because only five of the 23 correct responses were marked sure (four of 120 25 and one of 121 74), and there were ten cases of numbers marked sure which were wrong, indicating that the subjects probably called *sure* all those of which they *felt* sure. When a person in such an experiment learns the response by anticipation and confirmation, it is likely to form a sure memory.

Taken along with our other experiments this one seems nearly crucial against those theorists who have declared that association by contiguity has zero power.

Experiment 36

Series *Number Number 644* consisted of number pairs as described above, 8 pairs occurring 12 times each, 8 pairs occurring 9 times each, 16 pairs occurring 6 times each, 10 pairs of a meaningful sort (like *123 45* and *135 79*), 5 occurring 3 times each and 5 once each, 4 pairs occurring 6 times each in sequence, 24 pairs occurring 4 times each, 24 pairs occurring 3 times each, 48 pairs occurring twice each, 48 pairs occurring once each, and 24 pairs occurring once each, 12 at the very beginning and 12 at the very end of the series. No one of these last 24 pairs was included

in any test. The frequency of each two-figure number was as shown in Table 65.

TABLE 65

SERIES NUMBER NUMBER 644. FREQUENCIES OF EACH TWO-FIGURE NUMBER

Second Digit	First Digit									
	1	2	3	4	5	6	7	8	9	Total
0	1	5	5	4	1	7	2	1	4	30
1	4	4	23	3	9	8	3	7	6	67
2	4	1	7	8	6	3	10	4	6	49
3	5	3	6	8	12	27	6	8	10	85
4	17	18	15	8	3	3	12	12	3	91
5	7	4	5	8	8	6	7	11	6	62
6	1	12	18	6	7	3	9	0	15	71
7	8	10	22	4	5	7	3	2	7	68
8	7	5	9	3	5	7	3	10	5	54
9	4	13	10	8	3	12	4	12	1	67
Total	58	75	120	60	59	83	59	67	63	644

Series *Number Number 644* was read at the rate of 2 seconds a pair to 92 graduate students of psychology after the following instructions: "I shall read you a long list of three-place numbers like 726 or 439, and two-place numbers like 68, 21 or 47, in pairs. I shall read, for example, four ninety-seven twenty-one, three eighty-five sixty-four, nine thirteen twenty-seven, five eighteen twenty-four. You are to listen to the pairs of numbers as I read them, without making any effort to remember them or think about them. Just listen comfortably with just enough attention so that you can truthfully say that you heard all the numbers."

As soon as the list had been read, the subjects filled out two test blanks, A and B. Half the subjects filled out A first; the other half filled out B first. The test blanks contained the three-figure numbers of Tests A and B printed in Table 66, but in an order which distributed the pairs of 1, 2, 3, 4, and 6 repetitions equally throughout the test. The instructions at the top of the test blank were as follows:

After each of the numbers below write some number from 10 to 99. If you remember what number followed the three-

figure number in the experiment, write that number. If you do not remember, write the first number (from 10 to 99 inclusive) that comes into your mind.

The total number of correct responses for the 92 subjects was as shown in Table 66. Table 66 also contains a statement of the number of repetitions of each pair. 6*s* means 6 repetitions in sequence; 3*m* means 3 repetitions of a pair which easily suggests some association or system by which it may be remembered. The number of correct responses per hundred for each sort minus an allowance of 1.1 for successes to be expected by chance was as follows:

1	occurrence			0.4
2	occurrences			0.1
3	"			1.5
4	"			0.4
6	"			.1
12	"			3.8
6	"	in sequence,		6.5
3	"	123	45	66.3
1	"	369	33	−1.1
3	"	135	79	1.1
1	"	100	99	15.2
1	"	456	56	5.4
3	"	111	33	18.5

We may postpone any detailed discussion of these results until we have the results of similar experiments before us. They are uneven, partly because of the variation from pair to pair among those pairs having the same number of repetitions and partly because 92 subjects are not enough to measure accurately small strengthenings due to 2 or 3 or 4 repetitions.

In general the experiment agrees with all our experiments in showing that repetitions of a belonging sequence have a demonstrable strengthening effect even for three occurrences in a series of 644 (or of 4000), and that their effect is extremely weak compared to that of such meaningful sequences as 123 45 or 111 33.

Table 66

Results of experiment 36 with series number number 644

Number of correct responses to each pair from 92 subjects, for pairs occurring 1, 2, 3, 4, 6, and 12 times

Test A

	1			2			3			4			6	
138	33	0	151	40	0	133	30	2	153	83	0	129	37	0
213	98	0	224	11	1	222	17	2	223	27	1	329	89	2
307	29	3	319	87	0	387	68	1	475	95	2	378	36	1
520	34	0	521	32	2	555	57	19	659	92	1	647	81	1
537	12	0	541	44	0	826	44	0	250	31	4			
												6 in sequence		
542	45	1	543	36	0	853	45	3	131	38	0	269	43	6
658	93	0	663	77	0	946	90	0	998	46	1	519	88	6
673	62	1	707	47	2	854	84	1	211	25	0			
177	82	1	212	20	1	268	98	4	413	37	1		12	
252	92	0	694	94	3	942	14	0	708	73	1	148	63	6

Meaningful			
3 repetitions of	123	45	62
3 repetitions of	135	79	2
1 repetition of	369	33	0

Test B

	1			2			3			4			6	
152	42	3	154	59	1	147	31	2	162	74	3	260	52	2
164	71	0	176	68	1	150	28	0	188	13	0	343	61	2
477	63	0	479	85	2	485	67	3	538	14	2	407	73	1
522	35	0	536	39	3	692	21	2	698	19	1	693	18	0
652	13	0	656	11	1	853	39	0	272	75	3			
												6 in sequence		
544	64	3	651	40	0	856	56	6	145	39	3	361	31	8
664	78	1	672	61	0	947	65	0	175	91	1	614	27	14
695	90	0	737	55	1	948	83	1	305	17	2			
190	83	0	273	12	0	367	97	0	478	38	3		12	
274	22	0	697	63	2	133	30	3	736	60	1	196	37	3

Meaningful			
3 repetitions of	111	33	18
1 repetition of	100	99	14
1 repetition of	456	56	6

Experiment 37

The *bacon* series consisted of 3790 pairs of words and numbers. The series included:

8	pairs	occurring	48	times
8	"	"	42	"
8	"	"	36	"
8	"	"	30	"
8	"	"	24	"
8	"	"	18	"
8	"	"	12	"
42	"	"	6	"
27	"	"	3	"
12	"	"	6	times in sequence
10	meaningful pairs		3	times

It included also "doubles" or pairs in which the same word was followed in half its occurrences by one number and in the other half by a different number. Of these "doubles" there were:

8	pairs	with	the	two	numbers	occurring	24	times	each
8	"	"	"	"	"	"	21	"	"
8	"	"	"	"	"	"	18	"	"
8	"	"	"	"	"	"	15	"	"
8	"	"	"	"	"	"	12	"	"
8	"	"	"	"	"	"	9	"	"
8	"	"	"	"	"	"	6	"	"

A few pairs occurring once or twice only were used to complete the series.

The two-figure numbers occurred with frequencies ranging from 0 to 210, as shown in Table 67.

The following statement was made to the subject:

> I shall read you a long list of words and numbers in pairs like *bread 68, butter 21, milk 41, cheese 39*. The number will always be a two-figure number, that is, from 10 to 99. The same word may always be followed by the same number, or may be followed by two numbers, sometimes by one and sometimes by the other. You are to listen to the pairs of words and numbers as I read them, without making any effort to remember them or think about them. Just listen comfortably and with equal attention throughout.

Then the series was read at the rate of 1½ seconds per pair. Then the test sheets S and D shown below were given to the subjects with these instructions:

Instructions for the *bacon* test, Sheet S

Take the Test I sheet. Write after each word the number which came after it in the experiment. If you do not remember what number came after it, make a guess. Write some number after each word.

Instructions for the *bacon* test, Sheet D

Take the Test II sheet. Write after each word the two numbers which came after it in the experiment. If you remember only one, write it first and then make a guess at the other. If you remember neither, guess at both. Write two numbers for each word.

bacon Test S

bacon	....	enjoy	....	sedan	....
answer	....	canoe	....	secret	....
bold	....	disturb	....	silver	....
aim	....	gold	....	stand	....
belong	....	glen	....	shellac	....
bank	....	hasten	....	doctor	....
alloy	....	germ	....	rely	....
bead	....	hero	....	twins	....
arrange	....	lemon	....	Athens	....
alder	....	ham	....	roller	....
aged	....	herald	....	echo	....
chain	....	garlic	....	vote	....
cherry	....	clam	....	alto	....
chin	....	effort	....	sandy	....
china	....	graduate	....	funny	....
cigar	....	lizard	....	youth	....
cargo	....	map	....	Boston	....
career	....	palsy	....	sever	....
camp	....	lucid	....	brandish	....
bag	....	picnic	....	shell	....
beauty	....	major	....	colon	....
bushel	....	melon	....	Dover	....
desire	....	parlor	....	fickle	....
desk	....	cog	....	forlorn	....
devil	....	gas	....	halo	....
diet	....	octagon	....	Canada	....
dim	....	plot	....	Cuba	....
divine	....	ponder	....	England	....

bacon Test S (*Continued*)

door	....	rebel	....	France	....
drab	....	peg	....	load	....
border	....	rub	....	mercy	....
camel	....	poke	....	Mexico	....
discovery	....	rapid	....	Denmark	....
fatal	....	relic	....	Chile	....
favor	....	dumb	....	India	....
extra	....	hazel	....	Finland	....
food	....	revolutionary	....	Germany	....
fox	....	serene	....	Scotland	....
fast	....	soft	....	Rome	....
few	....	spider	....	Venice	....

bacon Test D

bias	dusty	malice
boiler	farmer	panic
atlas	ferry	plus
ailment	fix	radio
bench	elect	relax
amber	frog	pen
blemish	fabric	rush
cedar	escape	polish
cave	go	rash
cause	helmet	sickly
cat	geese	soda
carol	giant	spiral
cabbage	law	selfish
cable	hate	scrap
dike	gesture	sister
direct	locust	stop
dirty	maxim	
duty	party	
dismal	lend	
drill	piano	

In the case of one group of 8 (able undergraduate women students) each person did test sheets S and D entire, four doing S first and then D, four doing D first and then S. In the case of another group of 162 individuals (adult students in a summer session), there were four sub-

TABLE 67

Bacon TEST: FREQUENCY OF OCCURRENCE OF EACH NUMBER FROM 10 TO 99

Second Digit	First Digit 1	2	3	4	5	6	7	8	9	Total
0	0	0	0	9	6	0	6	3	6	30
1	15	9	12	12	0	0	39	69	6	162
2	36	36	126	183	15	6	39	6	9	456
3	6	57	15	6	102	138	144	21	84	573
4	3	72	12	33	111	162	160	75	27	655
5	3	69	12	3	111	9	57	9	27	300
6	129	144	84	15	0	15	144	18	210	759
7	12	87	75	159	3	45	12	12	21	426
8	12	171	6	36	42	9	18	6	18	318
9	9	33	3	15	0	6	24	6	15	111
Total	225	678	345	471	390	390	643	225	423	3790

groups, one doing the S sheet, *bacon* to *graduate* first and then half the D sheet; one doing the S sheet *lizard* to *Venice* first and then half the D sheet; one doing the D sheet *bias* to *gesture* first and then half the S sheet; one doing the D sheet *locust* to *stop* first and then half the S sheet. The records are treated in Table 68 as if 81 individuals had done all the sheets S and D.*

The number of correct responses is given in Table 68 for the 8 and 81 cases separately. It should be remembered that the pairs *Athens* to *Venice* with 6 occurrences each were at some disadvantage compared to the others, because they came late in the S test series. Except for these, the pairs of any given frequency of occurrence were spread over the test in a similar manner.

In scoring the pairs where one word was followed by two numbers, one correct response counted 1. If both numbers were given the count was 2. But if, as occasionally happened, an individual wrote one correct number twice for the word, the count was only 1.

* There were a few irregularities, such as omissions, reports of the same number twice in the D sheet, and slight inequalities between the numbers doing S first and those doing D first. These were treated reasonably, and the reader may safely assume that the comparisons made later are not invalidated by these irregularities in any prejudicial way.

Table 68

Number of correct responses for 8 college students and 81 summer school students

Occurrences			n = 8	n = 81
48	bacon	32	6	57
	chain	96	4	19
	desire	63	3	18
	fatal	42	4	25
	glen	24	1	10
	lizard	16	6	45
	plot	54	1	9
	serene	25	6	20
42	alloy	73	6	24
	career	16	8	24
	door	42	4	30
	few	93	3	6
	herald	55	2	11
	melon	76	3	17
	rapid	26	3	12
	stand	74	0	9
36	bank	74	2	14
	cargo	47	2	9
	divine	84	4	19
	fast	26	3	13
	ham	84	1	29
	major	27	5	15
	poke	75	3	6
	silver	64	2	20
30	belong	23	1	4
	cigar	42	7	46
	dim	55	1	11
	fox	64	1	15
	lemon	96	2	28
	picnic	37	3	22
	rub	12	3	32
	secret	28	5	13
24	answer	63	0	20
	cherry	36	2	21
	desk	47	2	10
	favor	81	0	5
	hasten	73	0	2
	map	42	1	27
	ponder	73	1	6
	soft	53	1	6
18	aim	63	0	9
	china	83	3	10
	diet	36	3	16
	food	26	1	6
	hero	73	1	8
	lucid	58	1	7
	peg	63	1	8
	sedan	74	1	21
12	bold	63	0	0
	chin	37	4	28
	devil	96	4	43
	extra	53	1	0
	germ	29	0	8
	palsy	34	2	10
	rebel	63	0	11
	spider	24	0	9

Occurrences			n = 8	n = 81
6	bead	26	0	5
	camp	42	0	1
	drab	49	0	4
	enjoy	89	1	2
	garlic	36	3	12
	parlor	69	0	6
	relic	55	0	0
	shellac	81	1	8
3	arrange	32	0	1
	bag	68	0	3
	border	98	0	0
	canoe	39	0	2
	clam	45	0	1
	cog	14	0	7
	dumb	57	0	11
	doctor	84	1	5
6s	alder	27	5	9
	beauty	43	1	6
	camel	88	1	12
	disturb	31	2	5
	effort	54	1	9
	gas	37	3	25
	hazel	91	3	19
	rely	99	1	12
	roller	13	1	20
	sandy	21	3	19
	sever	38	0	9
	shall	29	2	10
3m	aged	90	2	10
	bushel	32	0	7
	discovery	92	1	8
	gold	49	0	10
	graduate	14	3	14
	octagon	80	4	12
	revolutionary	76	3	29
	twins	22	5	61
	vote	21	0	5
	youth	17	3	16
24, 24	bias	76, 47	2	16
	cedar	32, 96	3	31
	dike	81, 53	3	23
	farmer	44, 67	5	56
	go	28, 47	2	22
	locust	26, 72	1	16
	plus	64, 47	0	51
	sickly	28, 54	5	28
21, 21	blemish	37, 28	5	12
	cable	47, 32	1	9
	dusty	76, 64	1	26
	escape	53, 96	3	10
	gesture	16, 79	3	10
	panic	58, 36	1	17
	rash	28, 22	4	17
	stop	67, 74	5	75

TABLE 68 (*Continued*)

Occurrences			n = 8	n = 81
18, 18	amber	64, 28	6	15
	cabbage	96, 48	3	47
	drill	95, 73	1	5
	fabric	27, 78	0	6
	hate	74, 93	1	8
	malice	94, 96	6	13
	polish	76, 73	2	9
	sister	28, 71	7	57
15, 15	bench	53, 64	2	5
	carol	74, 11	3	10
	dismal	36, 27	1	8
	elect	66, 28	2	6
	law	54, 75	3	12
	piano	76, 23	2	26
	rush	32, 25	2	8
	scrap	55, 72	2	10
12, 12	boiler	54, 96	2	17
	cave	58, 76	1	2
	direct	55, 18	0	9
	ferry	16, 22	4	12
	helmet	96, 26	3	20
	maxim	64, 77	2	12
	radio	27, 93	4	39
	soda	42, 97	0	24
9, 9	ailment	42, 19	1	15
	cat	33, 96	4	28
	duty	52, 98	1	51
	fix	62, 28	2	7
	giant	46, 95	2	10
	lend	85, 99	1	2
	pen	40, 29	1	14
	selfish	23, 94	1	11
6, 6	atlas	25, 59	1	6
	cause	41, 87	0	2
	dirty	50, 12	4	50
	fix	62, 28	2	7
	geese	35, 32	3	14
	party	70, 16	3	18
	relax	86, 24	2	10
	spiral	92, 26	2	10
6	Athens	29	0	6
	alto	68	0	6
	Boston	93	0	5
	brandish	48	0	0
	colon	57	0	5
	Dover	17	0	1
	fickle	86	0	1
	forlorn	52	0	5
	halo	92	1	4
	Canada	87	1	5
	Cuba	31	2	1
	England	42	2	6
	France	53	1	2
	load	35	0	1
	mercy	63	0	5
	Mexico	86	2	3
	Denmark	33	2	2
	Chile	44	1	2
	India	55	1	3
	Finland	71	0	0
	Germany	66	5	15
	Scotland	82	2	5
	Rome	23	0	5
	Venice	79	0	4

The *angel* series consisted of 3850 pairs of words and numbers like *act 10, adopt 93, allow 23, angel 51, atom 47*. All the numbers were within the limits, 10 to 99. Some words always were followed by the same number; some were not. The frequency of occurrence of a word varied from 3 to 96. The series included:

3 words followed by the same number 48 times
8 words followed by the same number 24 times
36 words followed by the same number 12 times
56 words followed by the same number 6 times
160 words followed by the same number 3 times
4 words followed by one number 24 times, by two numbers 12 times each, by four other numbers 6 times each and by eight other numbers 3 times each.

4 words followed by one number 24 times, by two other numbers 12 times each and by four other numbers 6 times each.
4 words followed by one number 24 times and by two other numbers 12 times each.
4 words followed by two numbers 12 times each.
10 words followed by one number 12 times and by two other numbers 6 times each.
8 words followed by one number 12 times, by two other numbers 6 times each and by four other numbers 3 times each.
16 words followed by one number 6 times and by two other numbers 3 times each.
8 words followed by two numbers 6 times each.
1 word followed by four numbers 6 times each.

The remainder of the series consisted first of certain meaningful pairs occurring three times, viz., *cube 27, foot 12, half 50, last 99, pound 16, quarter 25, thirty 30, score 20, unlucky 13*, and *yard 36*; second, of 2 pairs occurring 6 times in sequence and 6 pairs occurring 3 times in sequence; third, of ten words occurring once each placed at the end of the entire series; fourth, of a few words occurring 3 or 4 times each with only one or two words intervening between their occurrences, and, fifth, of the words *one, two, three*, etc., to *nineteen*, and *firstly, secondly*, etc., to *sixthly*, occurring from 1 to 20 times each, used irregularly to expand the series. Details will be found in Appendix IV.

These word-number pairs were so arranged as to be distributed approximately evenly throughout the entire series, i.e., even for the most common words, such as *angel* or *praise*, there would be a gap of approximately forty pairs between occurrences. In the case of words occurring less frequently, the gaps would be wider. The series as a whole was so arranged as to measure the influence of repetition from three to forty-eight times in number; and so as to measure the influence of conflicts between the use of different numbers for the same word; and also so as to measure the influence of frequency of occurrence of the second terms

of the pairs. The two-figure numbers did not occur equally often, but with frequencies as shown in Table 131 of Appendix IV.

Experiment 38

This *angel* series was read to eight university students (Group A) at one sitting, at the rate of 3 seconds per pair, after the following instructions had been given:

> I shall read you a long list of words and numbers in pairs, like *bread 68, butter 21, milk 47, cheese 39.* The number will always be a two-figure number, that is, from 10 to 99. The same word may or may not be always followed by the same number.
>
> You are to listen to the pairs of words and numbers as I read them, without making any effort to remember them or think about them. Just listen comfortably and with equal attention throughout.

The subjects of the experiment then were tested as follows:

> Take the Test I sheet. Write after each word the number or numbers which came after it in the experiment. If you do not remember what number or numbers came after it, make a guess. Write some number after each word. Then do the same for the Test II sheet.

For half the subjects the instructions were changed so that they did test sheet II first and test sheet I second.

For the 13 subjects of Group B, the experiment was the same except that the reading was spread over three sittings (March 15, 16, and 21), and all subjects did test sheet I first, and test sheet II second. Immediately after the final reading on the third day, the subjects were asked to write after each of the words shown in Tables 129 and 130 of Appendix IV the number which went with it or went with it oftenest.

If they remembered more than one number as an associate of that word, they were to write the additional ones. If they did not remember any number as an associate of

that word, they were to write the first number that came into their heads, or just to guess.

Test I and Test II for the *angel* series included a sampling of the different frequency types as shown in Appendix IV. In Tables 129 and 130 of that appendix the headings show the frequencies. The entries show the numbers which were read after the words in question.

The results for the *angel* experiment "singles" are shown in Table 132 of Appendix IV. The results for the multiples are shown in Table 133 of Appendix IV.

§ 4. The amount of strengthening caused by the repetition of a sequence with belongingness, but no satisfyingness

It is possible to make a plausible, even a rather strong, defense for the hypothesis that repetition with belonging but without any satisfying effects does not strengthen connections at all. The excess above chance may be explained by assuming first that certain pairs possessed meaning as in *hexagon 88*, or acquired meaning by virtue of some special thoughts of the subjects, second that even though honestly trying to obey the instructions the subjects will often anticipate the response and be more satisfied when they anticipate it correctly than when they do not. The great variation amongst pairs equally often repeated (for example, from 100 percent correct for *246 32* to 0 percent correct for *383 42* both repeated 96 times with the eight college students, and from 53 percent right for *devil 96* to 0 percent right for *extra 53*, with eighty-one summer school students) is more easily explained by assuming that meaningfulness and anticipatory reactions play a very large rather than a small rôle. Why not let them be the entire cast? Since with some pairs with some persons a frequency of 96 occurrences demonstrably fails to make a connection strong enough to last into the test period, is it not better to assume that it in general has zero influence? So it may be argued.

As counter arguments we may note (1) the improbability that students of psychology would often violate instructions by seeking meaningful associations, or that, in the experiments where pairs were copied or written from dictation, anybody would often do so.

We have evidence that thinking of meaningful associations between the first and the second terms of the pairs was rare in the fact that tempting opportunities to do so were not much used. Among the meaningful pairs occurring three times each in the *angel* series, *last 99* was no more often correct than the average neutral pair with three occurrences, and *cube 27*, *foot 12*, and *half 50* showed only 6 rights out of a possible 21. Among the meaningful pairs occurring three times each in the *bacon* series, *vote 21* was only a little more often correct than the average neutral pair with three occurrences. *Bushel 32*, *discovery 92* and *gold 49* averaged only 8.7 correct to 3.9 for the average neutral. In the *Number Number 644* series, *135 79* was not given correctly by any of the 14 individuals who heard it three times or by any of the eight individuals who heard it six times; *369 33* was given correctly by only one and *456 56* by only two.

We may note (2) the improbability that anybody in these copying and dictation experiments would be much more satisfied by right than by wrong anticipations of a number in thought, though in the listening experiments there is a real and considerable feeling of comfort and success in so doing, valueless though the achievement may be so far as the subject then knows. (3) The variation in number correct for pairs equally often repeated, though wide, is not easily analyzable into pairs with 0 or 1 or 2 percent correct for sheer repetition plus belonging plus chance and pairs with a substantial percent correct indicating the addition of meaning or anticipatory responses by the subjects. (4) The variation among individuals from those having not a single one right out of, say, sixteen pairs each repeated 15 or more times to individuals having a dozen or

more rights is also not a separation into two groups with a clear gap. It is a unimodal continuum. (5) In all this we must remember that each occurrence of a pair even of those occurring oftenest was separated from the next occurrence by fifty or more pairs intervening, so that a certain amount of strength might be added by each occurrence, but be mostly lost by disuse and interference before the next occurrence. Consequently, the fact that a person gets no more right answers in the test than chance would give need not mean that the repetitions have done nothing in his case. They have simply failed to bring the strength of any pair safely beyond the point where he will write it correctly in the test. Conceivably a person who scored 0 out of 8 for pairs occurring 21 times might score 8 out of 8 if the pairs had occurred a little more closely together.

The influence of the repetition of a connection in these experiments may be shown in another way, namely, by using the connections between "any word heard in the experiment" and "the number following and paired with it." In the *bacon* series, *10*, *20*, *30*, *51*, *56*, and *59* and some other numbers did not occur at all, whereas *42* was paired with some word or other 183 times, *96* was paired with some word or other 210 times. If now we study the wrong responses in the test, for individuals who reported that they wrote the first number that came into their heads, without considering or making allowance for the fact that some numbers occurred often and others rarely,* we find that *42*, *96* and other numbers occurring frequently in connection with "a word heard in the experiment" are given much oftener than *10*, *20*, *30*, *51*, *56*, *59*, etc. Using the total count for 57 individuals, the correlation between frequency of occurrence in the series and frequency of occurrence in the wrong responses in the test is .60. The median number of wrong responses is over three times as great for a number occurring 100 or more times in the series as for a number occurring 6 times or less. Details appear in Table

* Many of them probably were not even aware that such was the case.

69. Before accepting the records of Table 69 as a proof of the influence of frequency of occurrence, we must, however, consider another possible influence, that of the satisfyingness of anticipatory reactions during the experiment and of correct responses recognized to be such in the test. An individual who had been satisfied by hearing *42*, *96*, etc., as a response to "a word in this experiment," would, by

TABLE 69

THE RELATION BETWEEN FREQUENCY OF OCCURRENCE OF A NUMBER IN THE *bacon* SERIES AND NUMBER OF TIMES THE NUMBER OCCURRED (1) AS A WRONG RESPONSE AND (2) AS A CORRECT RESPONSE, IN 57 INDIVIDUALS

	Average Frequency		
Numbers	In the Series	As a Wrong Response	As a Correct Response
10, 20, 30, 51, 56, 59, 60, 61	0	31	0
14, 15, 39, 45, 57, 80	3	49	3
13, 38, 43, 50, 62, 69, 70, 82, 88, 89, 90, 91	6	47	4
19, 21, 40, 65, 68, 85, 92	9	58	4
17, 18, 31, 34, 35, 41, 77, 87	12	68	2
11, 33, 46, 49, 52, 66, 99	15	42	4
78, 79, 83, 86, 94, 95, 97, 98	22	34	2
12, 22, 29, 44, 48, 58, 67, 71, 72	38	68	13
23, 24, 25, 27, 36, 37. 75, 81, 84, 93	73	103	15
16, 26, 32, 53, 54, 55, 63, 73	128	99	24
28, 42, 47, 64, 74, 76, 96	174	122	47

the law of effect, tend to favor these numbers. We therefore count, for the same group of individuals, the number of times each number from 10 to 99 was given in the test as a *correct* response, and compute the partial correlation between frequency in the series and number of wrong responses, for numbers which were given equally often as correct responses. This is .26.* (The correlation between frequency in the series and frequency among correct responses is .76; that between frequency among correct responses and frequency among wrong responses is .61.)

Thus it appears that frequency of occurrence in the series not only strengthens the special connections between certain particular words and their numbers, but also strengthens the connections between the thought of *any* word as in the series and certain numbers.

Additional evidence that the repetition of a belonging sequence strengthens the connection even though there is no satisfying after-effect will appear when we study the comparative strength of satisfying and annoying consequences in weakening connections. We shall find that under certain conditions making a wrong response and being told that it is wrong does not weaken but actually strengthens the connection. The connection gains more strength by occurring than it loses by the announcement that it is wrong.

As was stated earlier, the experiments with copying and writing from dictation seem to be nearly or quite crucial, and the total body of facts seems more satisfactorily explained by attributing power to sheer repetition of a connection, or sequence plus belonging.

The learning is, however, certainly very slow. This has been abundantly shown by the records, but may be illustrated more vividly by certain experiences of the author and of two individuals who typed the various series.

I prepared the *bacon* series of about four thousand pairs

* The partial *r* between frequency among wrong responses and frequency among right responses, for numbers which occurred equally often in the series, was .30.

like *bread* 27, *door* 16, *advance* 98, in which certain pairs occurred 48 times, others 24 times and so on. I selected the pairs; I then wrote out the entire series pair by pair; a week or so later I read three-fourths of the entire series to a group in an experiment. I then tested myself with the three pairs which occurred 48 times and the ten which had occurred 24 times in the series. I had considered the former attentively at least 85 times each, and the latter at least 43 times each. I got one of the three right and three of the ten. Approximately ten minutes after a stenographer had copied the entire list, I asked her to write any numbers that had followed certain of the words, these words being given to her on a sheet. She had none right of the three occurring 48 times and only three right of the ten occurring 24 times. In my own case, the record was improperly high because in reading the series I sometimes guessed what the number would be as soon as I saw the word and before I saw its number. When I guessed right, the satisfaction of doing so may have strengthened the connection. I also occasionally repeated a pair in inner speech after reading it aloud. On the other hand, the 85 or 48 or 24 repetitions in this experiment are probably weakened by interference from the intervening pairs. Learning would probably be more rapid if the intervals were filled with rest or with less interfering activities. Even so, it would be very slow.

Another individual, an able graduate student and a rapid learner in general, typed a series of 1208 pairs containing some that occurred from 3 to 21 times each. She did this in the ordinary course of her duties, with no expectation of being tested in any way. Her percentage correct in a test two hours later was 12½ percent for the 15's, 18's and 21's taken together. By chance alone she should have had 1.1 percent.*

* She had three of the four meaningful pairs right. Of the neutral scattered 3, 6, 9, 12, 15, 18, and 21 repetition pairs, she had one right out of the 8 6's, 2 right out of the 8 12's, and one each right out of the 4 18's and the 4 21's. She had one right of the 4 sequences of 12, one right of the 4 pleasant-word 12's, and one right of the 4 unpleasant-word 3's.

Occurrence in close sequence with that degree of belonging which attached a number to a word or number in these experiments is a real force, but not one strong enough to be relied on in practice to accomplish much for learning. Nor is attention to the occurrences all that is lacking. There was fairly close attention in the copying and dictation experiments, but very little learning.

For efficient learning of such pairs it is not enough to have them occur together and attend to them as they occur. The mind should also have the attitude or "set" toward forming and preserving the connection; it should itself make the response; and it should be satisfied by success in so doing either as an immediate result of the trace left by an occurrence or as an anticipatory response to hearing the first member of a pair.

If a person wished to strengthen the connections between, say, the three-place numbers and the two-place numbers as much as possible in two hours, he would not rely on repetition and attention alone. He would try to arouse interest in the learning, and would recall each pair from within after he heard it and before the trace left by the hearing had become ineffective, and would be pleased when he so recalled them and when later he could evoke the second term upon hearing or seeing the first.*

§ 5. The limitations of the action of connections by the mind's set or adjustment

In such experiments, connections are formed whereby *act* evokes *10*, or *120* evokes *25*, provided that one thinks of *act* or *120* in coöperation with a set of the mind toward thinking of some number from 10 to 99, or toward remembering what happened in the experiment, or toward contemplating the problem of connection-forming and data concerning it, or the like. Without some such appropriate

* He would, of course, also reduce the interference due to the chaotic arrangement of the pairs, and would make the connections meaningful where it was useful to do so.

contributory set of the mind the hearing or seeing of *act* and *120* has a very much weaker tendency to evoke *10* and *25*. For example, the writer, after having planned these series of pairs, written them out, read them several times, scored or tabulated many test results from them in several ways, and examined these tabulations, had a very strong tendency for the following year to think that *act* was followed by *10* and *twins* by *22*, if he thought of *act* or *twins* in the setting of the experiment, but he read several articles about twins without ever having the word evoke 22, and never thought of 10 in the hundreds of times that he must have seen the word *act* in his general reading. He does not remember ever having any word in his general reading evoke any two-place number in a way attributable to the experiments.

The importance of the contribution of the mind's general and special sets has been emphasized by the writer elsewhere ['14, pp. 24-26] and will be considered later in more detail. The early British associationists paid insufficient attention to it.

All that I have said or shall say here about the strength of these word number or number number connections concerns their strength, when they act in coöperation with the set toward thinking of a number from 10 to 99 with the aid of such dispositions as have been created by the experiments. The task of the test sheets put this set and these dispositions into action.

§ 6. The relation between the number of repetitions of a connection and increases in its strength

This relation is of interest in general and of especial interest in two respects, namely, the possible existence of a threshold number of repetitions below which no effect is observable,* and the possible existence of a law of dimin-

* It can, I think, be shown from many experiments on learning and memory that the first, second, and later repetitions all have some effect. The question is whether their effects are observable per se or only after summation.

ishing returns whereby one repetition has less and less effect according to the number of repetitions which it augments.

Our experiments present us directly with the relation between percent of correct responses for groups of connections in a group of individuals and number of repetitions, after allowance for chance; and this relation is presented in Table 70 and Figure 1 for comparable connections. But the strength of a connection from 0 to 1.00 and the percent of correct responses from 0 to 100 in a group of individuals are two different things and we must be cautious in our inferences.

What we wish to know is the probability of correct response for the same connection in the same mind, according to the number of its occurrences. This cannot be measured directly by any means whatsoever. If the same connection occurred six times in a thousand minds alike in all respects, we could reasonably assume that the probability of correct response found for the thousand would be roughly true for any one of them and closely true for the average of the minds. If from two thousand connections of the meaningless word-number type, four sets of five hundred were taken at random and repeated 6, 12, 18, and 24 times in such long scattered series as ours, the average or median number of correct responses for any five hundred would be the same as that for any other five hundred *by the same mind* except for the influence of the number of occurrences.

The defects in our experiments are that the 89 or 21 or 200 minds in any experiment are by no means alike, and that the number of pairs is too few (eight as a rule for each frequency of occurrence in each experiment). The latter defect is not serious, being productive only of "variable" or "accidental" errors which more experiments of the same sort can reduce and finally eliminate.

The former error is serious and incurable save by selecting subjects who are alike. In our *adopt* series, for exam-

ple, among the 100 inattentive subjects some have five times as many correct responses as others. The same is true among the attentive 100. Conceivably there may be some subjects who would show no correct responses at all for

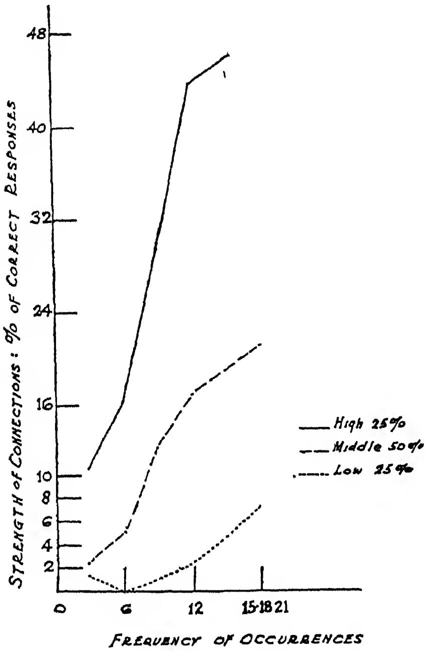

FIGURE 1. The relation between frequency of occurrences and percent of correct responses in the lowest 50, middle 100, and highest 50 subjects with the *adopt* series, using averages. In the score for 15, 18, and 21, these are given equal weight. The short dashes, long dashes, and continuous line refer to the lowest 50, middle 100, and highest 50, respectively.

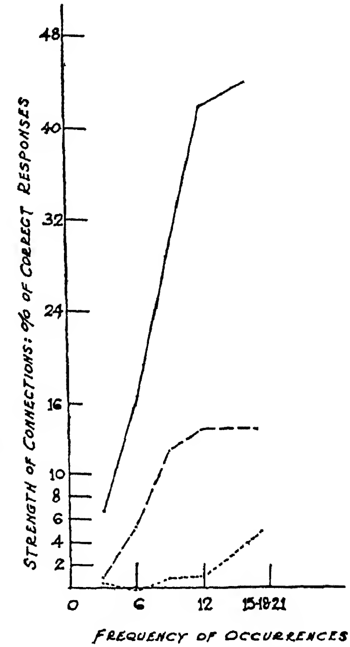

FIGURE. 2. Same as Figure 1 except that medians are used instead of averages and that in the 15, 18, and 21 score, 15 is given as much weight as 18 and 21 together, the points being set above 17.25.

pairs occurring 12 times, and other subjects who would have all such correct. For the former, the inattentive group, we might have a curve with 0 at 3, 6, 9, and 12 and, say, 100 per mille at 15, 200 at 18, and 300 at 21. For the latter, the attentive group, the curve might be 250 at 3,

TABLE 70

THE RELATION BETWEEN NUMBER OF OCCURRENCES OF A CONNECTION AND THE PER MILLE OF CORRECT RESPONSES, LESS AN ALLOWANCE FOR THE EFFECT OF CHANCE

Correct Responses per 1000

Occurrences	*bacon* series n=89		*angel* series n=21		*adopt* series n=200		*Number Number* 3568 n=8		*Number Number Number Number* 3568 n=14	*Number Number Number Number* 644 n=92
	Singles	Doubles	Singles	Doubles	Inat.	Atten.	Singles	Doubles	Singles	
3	31		92		37	46			−2	15
6	49	69	92*	48	47	86	52		−1[illegible]	1
9		85			91	188				
12	158	85	169	†	174	227	20	9	−2	38
15		50			121	234				
18	124	110			284	359		56	−11	
21		119			189	319				
24	133	170	294				40	48	7	
30	261							48	34	
36	196						10	64	34	
42	217							9	16	
48	318		338				130	87	78	
60							67			
72							98			
84							102			
96							270			

* *hexagon 88* is included here.

† Only two pairs were used with 12 occurrences, so the material is too scant to deserve consideration.

500 at 6, 750 at 9, 1000 at 12, 1000 at 15, 1000 at 18, and 1000 at 21.

The curve for the low 50 differs markedly from the curves for the middle 100 and high 50 in the *adopt* series. They are shown in Figure 1 for the averages and in Figure 2 for the medians.* The low 50 show a greater gain from 12 to 15, 18, and 21 than from 0 to 6, or 6 to 12 occurrences. The other two groups show much less gain from 12 to 15, 18, and 21.

Our facts are conditioned partly by the number of occurrences, but very largely also by the intermixture of minds acting differently. We need thousands of individuals instead of hundreds, so as to permit classification in all the experiments like that made for the *adopt* series, but much finer.

We may best now examine the facts. Figure 3 shows the five curves for the word-number experiments. There is,

* For the numerical data, see Table 70.

on the whole, an influence of even as few as three repetitions. The irregularities are great in spite of the large number of subjects and we must combine the different

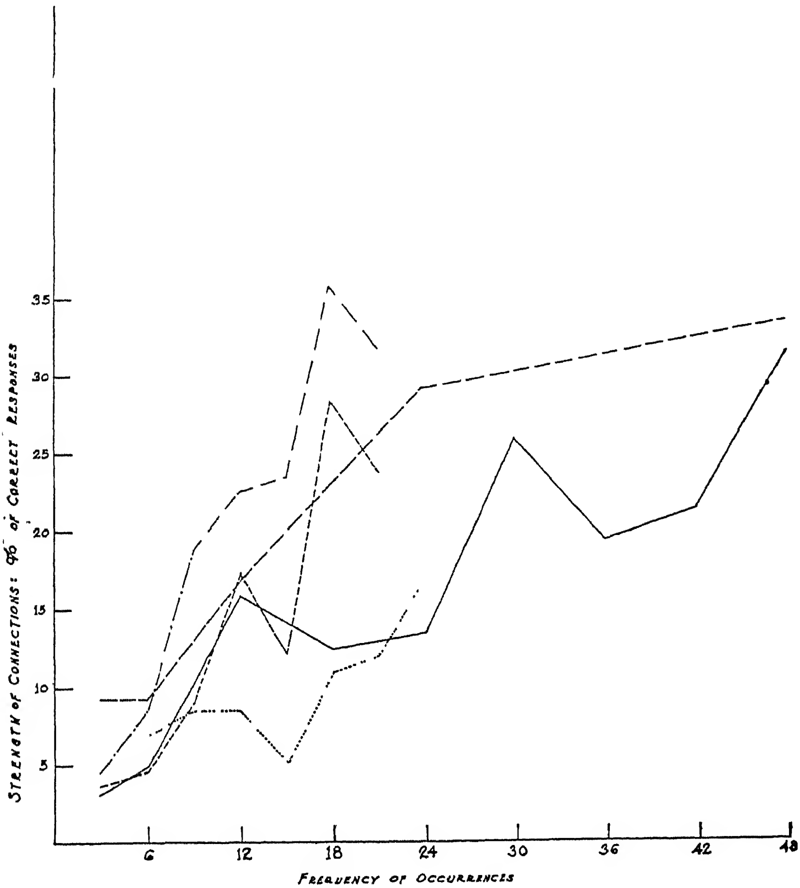

FIGURE 3. The relation between frequency of occurrences and percent of correct responses after allowance for chance successes in the case of *bacon* series singles (continuous line), *bacon* doubles (dotted line), *angel* singles (long dash line), *adopt* singles for the inattentive (short dash line), and *adopt* singles for the attentive hundred (short and long dash line).

curves in some reasonable way before we can estimate conveniently their general drift. We may use the records at 6, 12, and 18 occurrences, combining 9, 12, and 15 under 12,

and 15, 18, and 21 under 18, and for the *angel* series estimating 18 from 12 and 24. Doing this, and giving approximately equal weight to *bacon* single, *bacon* double, *adopt* inattentive and *adopt* attentive, and about one-third weight to *angel* single, we have effects from occurrences 1 to 6, 7 to 12, and 13 to 18, to raise the number of correct responses from that due to chance alone by K, 1.05 K and .47 K. From 18 occurrences on, the material is much less adequate. So far as it goes it shows an influence of occurrences 13 to 24 less than half that of occurrences 1 to 12, and an influence of occurrences 24 to 48 less than half that of occurrences 1 to 24.

In the *Number Number* series, on the contrary, what data we have show occurrences 25 to 48 causing a greater increase than 0 to 24, and occurrences 49 to 96 causing a greater increase than 0 to 48.

From our data as a whole, it appears probable that the influence of actual occurrences shows little evidence of diminishing returns up to the point where a strength of 100 to 200 per mille is reached. And they do not absolutely disprove the hypothesis that one occurrence adds the same amount of strength whenever it occurs, the apparent diminution being possibly due to the effects of mixture noted above and to other factors, such as the acceptance of certain pairs as learned and the devotion of attention to other pairs by subjects who disregarded the instructions. There are many other complicating factors.

By using series containing the same pairs but changing the frequencies so that certain pairs occur 3 times in one series, 6 in another, 9 in another, and so on, by close classification of subjects, and by modifications of method to reduce inner repetition, anticipatory responses, and uneven attentiveness, we can obtain much more light upon the question of the potency of each of a series of successive scattered occurrences of a connection.

In an experiment to the same end but by a very different method, Dr. Irving Lorge has found the relation between

number of occurrences of a connection and resulting strength shown in Figure 4. In it there is no evidence what-

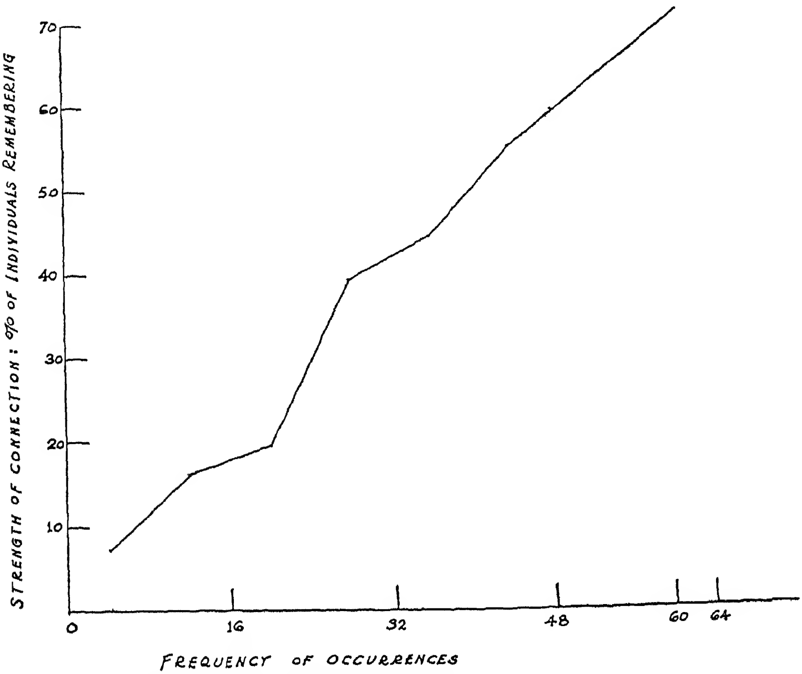

FIGURE 4. The relation between frequency of occurrences and the resulting strength of connections from the data of Lorge. (Appendix V.)

ever of diminishing returns from added occurrences up to 60. The details of his experiment are presented in Appendix V.

§ 7. INTERFERENCE, INDEPENDENCE, AND REINFORCEMENT FROM ADDITIONAL CONNECTIONS WITH THE SAME FIRST TERM

The facts of interference in learning in general which are due to additional connections with a situation may conveniently be grouped as follows:

I. Multiplicity of response to the same situation.

A. Cases where $S_1 \rightarrow A$, $S_1 \rightarrow B$, $S_1 \rightarrow C$, etc., are all acceptable and right, as in writing *tho* or

though when required to spell the word or as in responding to *"Tell me a boy's name"* by *John* or *Dick* or *William* or *Peter.*

B. Cases where $S_1 \longrightarrow A$ is right, whereas $S_1 \longrightarrow B$, $S_1 \longrightarrow C$, etc., are wrong or less acceptable as in writing *traveling, travelling* and *travveling* when required to spell the word, or as in responding to *"Tell me the name of a great musician"* by *Bach, Sullivan or Troubetski.*

II. Multiplicity of responses to a situation occurring with slight variations.

C. Cases where $S_1 + s_1 \longrightarrow A$, $S_1 + s_2 \longrightarrow B$, $S_1 + s_3 \longrightarrow C$, etc., are all acceptable and right as in responding to *"Tell what you know about Christopher Columbus"* by (a) *He discovered America,* (b) *in 1492,* (c) *was sent by Ferdinand and Isabella,* and (4) *was an Italian.**

D. Cases where $S_1 + s_1 \longrightarrow A$, $S_1 + s_2 \longrightarrow B$, etc., include statements that are incorrect or less correct than some other, or acts that are wrong or less right than some other.

From our experiments facts are available concerning interference of Type A (or Type C, if the individual thinks first "*angel,* what number" and having thought 42, then thinks "*angel,* what number besides 42").

If one word, say, *answer,* is followed always by the same number let us say, *63, n* times, and another word, say, *bias,* is followed by *76* n times and by *47* n times, the occurrences of the second sequent in the latter case may conceivably interfere with *bias* $\longrightarrow$ *76,* making it less strong than *answer* $\longrightarrow$ *63.* Or they may reinforce *bias* $\longrightarrow$ *76* by calling it to mind or increasing attention to *bias* and its sequent when it occurs, or perhaps in subtler ways.

* In this illustration the S_1, S_2, S_3, etc., are the individual's tendencies to think, "Who was he?" "When did he live?" "What did he do?" "What more do I know about him than I have already said?", etc., etc.

It is of interest to observe what does actually happen in our experiments in these respects. The simplest case is the comparison of single and double connections in the *bacon* series.

The average number of "correct" responses per 1000 for singles and for each one of the two doubles was as shown in the first two lines of Table 71. The corresponding medians are shown in lines 3 and 4.

TABLE 71

CORRECT RESPONSES PER THOUSAND, FOR OCCURRENCES OF 30, 24, 21, ETC., IN THE *bacon* SERIES

	30	24	21	18	15	12	9	6
	Obtained per Mille							
1. Av. Singles	272	144		135		169		60
2. Av. Doubles		191	140	131	71	106	106	90
3. Med. Singles	241	107		101		112		51
4. Med. Doubles		182	108	93	68	108	83	74
Less allowance for chance								
5. Av. Singles	261	133		124		158		49
6. Av. Doubles		170	119	110	50	85	85	69
7. Med. Singles	230	96		90		101		40
8. Med. Doubles		161	87	72	47	87	62	53

These averages and medians less the number of correct responses to be expected by mere chance are given in lines 5 to 8. The correction for singles is, of course, to subtract 11, there being one chance in 90 of getting the correct number by chance alone. The correction for doubles is more complicated. Since there are two numbers either of which is right, the first number set down by a subject has two chances in 90 of being correct by chance. But if one of the numbers set down is correct, the second one set down has only one chance in 90 of being correct by chance. For the same number set down twice would be counted as correct only once. The correction will then never reach quite to 22.22 and will vary according to the percentage of individuals having one or both numbers correct.

I have computed this percentage from a sampling of 37

individuals' records for doubles of 24, 21, 18, 15, 12, 9, and 6 occurrences. The correction varies from 21 to 21½. The variation being so narrow, I have used 21 as the correction for all doubles. On the whole, the singles have the advantage, but it is not great or surely demonstrable. There probably is interference of one connection with the other in a double in general, but it is counterbalanced by reinforcement in some cases. The evidence for this last statement is the frequency of cases where both numbers are right. This is above what chance would give for the greater frequencies. For the cases of 18, 21, and 24 repetitions combined (involving 4272 numbers, 2136 responses of two numbers each) we find 116 responses with both numbers correct and 426 with one number correct.

In the *bacon* series which we have just dealt with the subjects of the experiment knew beforehand that the word had either one number or two as its complement, and so could think "It is——" or "It is —— or——." In the *angel* series they did not know beforehand anything about the construction of the series save that "the same word may or may not be followed by the same number."

We first compare the results for words occurring 24 times with one single number with those of words occurring 24 times with one number, 12 times each with two other numbers, 6 times each with four other numbers, and 3 times each with eight other numbers.

For the thirteen subjects in March, 1928, the ten singles showed 46 correct responses or 354 per thousand, or 343 per thousand above chance. The four multiples showed 13 responses where the number that occurred 24 times was given. There were 58 responses; hence, this is equivalent to 224 per thousand or 213 per thousand above chance.

For the eight subjects in June, 1928, the corresponding results are 214 per thousand above chance and 94 per thousand above chance.

We next compare words occurring 24 times with one single number with words occurring 24 times with one, 12

times each with two other numbers, and 6 times each with four other numbers. The results here were:

For 13 subjects, March, 1928, 343 per M versus 345 per M above chance, for singles and multiples, respectively.
For 8 subjects, June, 1928, 214 per M versus 94 per M above chance, for singles and multiples, respectively.

We next compare the words occurring 24 times with one single number with words occurring 24 times with one, and 12 times each with two others. The results were:

For the 13 subjects, 343 per M versus 174 per M.
" " 8 " 214 per M " 132 per M.

In the same way we compare the results for words occurring 12 times with one single number with those where words occurred 12 times with one number, 6 times each with two numbers, and 4 times each with three numbers. The results were:

For the 13 subjects, 192 per M versus 82 per M.
" " 8 " 132 per M " 60 per M.

When the comparison is with words occurring 12 times with one number and 6 times each with two numbers, the results were:

For the 13 subjects, 192 per M versus 180 per M.
" " 8 " 132 per M " 125 per M.

Using the records for words occurring 6 times with one number* and 6 times with each of four numbers, the results are:

For the 13 subjects, 56 per M versus 18 per M.
" " 8 " 83 per M " 67 per M.

Using the records for words occurring 6 times with one number and 6 times with each of two numbers, the results are:

* Omitting *hexagon 88*, which is remembered about 5 times as often as the average. If this is included, the amount of interference reported would be much greater.

For the 13 subjects, 56 per M versus 73 per M.
" " 8 " 83 per M " 7 per M.

We may now examine the interference in the pronounced cases where a frequency of 12 occurs along with another frequency of 12, one of 24, four of 6, and eight of 3. The results were:

For the 13 subjects, 192 per M versus 21 per M.
" " 8 " 132 per M " 39 per M.

For the somewhat less pronounced cases where the interference is due to another 12, one 24, and four 6's, the results were:

For the 13 subjects, 192 per M versus 73 per M.
" " 8 " 132 per M " 22 per M.

In general, then, there is interference under the conditions of these experiments in the sense that the connection formed by *n* occurrences of A⟶B is weaker if there are also occurrences of A⟶C, or of A⟶C and A⟶D, or of A⟶C, A⟶D, A⟶E, etc. How far this interference is due to fundamental general physiological facts, is a question not settled by these experiments. It may be due in some measure to relatively superficial and specific facts, such as the habit of attending more to pairs judged to be of the *A⟶one* sort than to pairs judged to be of the *A⟶many* sort.*

§ 8. Factors productive of variations in gain in strength from the same number of occurrences

For each set of pairs alike in the general nature of the pairs and the number and position of the repetitions, we have taken the pair showing the strongest connection in

* A hasty consideration of the probable nature and influence of such specific facts leads me to assign rather a small rôle to them and to expect that interference is a general fact. The potency of *n* repetitions of A⟶B within a given time seems to me to depend not only upon their distribution in that time and upon what in general fills the remainder of the time, but also especially upon what else has been connected with A, additional connections therewith tending to reduce the potency of the *n* repetitions of A⟶B.

the test and the pair showing the weakest. The facts appear in Table 72. The pairs which were deliberately made meaningful, such as *unlucky 13*, *twins 22*, *444 44*, and *123 45*, and those which were deliberately made to include words of pleasant and unpleasant reference are not included in this comparison, but are treated separately in Table 72A.

As would be expected, any feature of a pair which makes the occurrence of its number in that connection have a probability (apart from memory itself) greater than 1 in 90 or makes the right number more easily recognizable as right if one does think of it, seems to favor the learning, as in *noisy 14*, *curl 15*, *cadet 16*, and *prince 26*, and perhaps *date 96*. Any more subtle features which encourage thoughts about the connection or meaningful associations which tend to limit selection or facilitate recognition favor the learning. *Dome 50*, *margin 13*, and *hexagon 88*, are perhaps cases of this sort. *Duty 51* is a special case of this sort due to the fact that *dirty 51* occurred in the same series. But there are only nine cases in all out of the 94 of Table 72 which seemed due to the pair as a pair. In the others the second number was for some reason easier to connect with anything, or the first member was more likely to win attention and interest.

Pairs whose second member is a doublet like 11, 22, 33, or a sequence like 12, 23, 34, 45, or a round number like 10, 15, 20, or 25, occur about twice as often in the pairs easy to learn as in those hard to learn.

The value of attention and interest in the word (with occasional special exceptions such as a person's age, his street number, or the like, the numbers are, of course, all of about equal and very slight interest) appears not only in the comparison of the words deliberately chosen for pleasant or unpleasant reference with those chosen at random, but also among those chosen at random in the great strengthening of connections with *candy*, *cigar*, *ham*, *bacon*, *blond*, *devil*, *garlic*, and *dirty*. Perhaps *camel* (the ciga-

Table 72

PAIRS WHOSE TWO MEMBERS WERE STRONGLY OR WEAKLY CONNECTED BY EQUAL NUMBERS OF REPETITIONS

Pairs chosen to be meaningful or to have pleasant or unpleasant connotations are not entered in this table, but in Table 72 A

adopt Series

n	Strong		% C.	Weak		% C.
3	noisy	14	14.5	fence	86	0.5
3s	city	95	13.5	pick	86	1.0
6	curl	15	19.5	ledge	62	1.0
6s	dome	50	25.0	mixer	73	1.5
9	mason	25	22.0	denote	18	4.5
9	candy	52	29.5	remove	87	2.5
9s	blond	60	39.0	mitten	42	5.5
12	margin	13	38.0	rafter	92	4.0
12s	Dodge	72	25.0	bishop	39	7.0
15	camel	37	38.0	neglect	64	3.5
18	adverb	10	65.5	crude	31	8.0
21	album	41	36.0	paste	75	6.0

bacon Series

n	Strong		% C.	Weak		% C.
3	dumb	57	12	border	98	0
6	garlic	36	17	relic	55	0
6	Germany	66	19	Finland	71	0
6s	gas	37	31	disturb	31	8
12	devil	96	53	bold	63	0
18	diet	36	21	food	26	8
18	sedan	74	25	aim	63	10
24	map	42	31	hasten	73	2
30	cigar	42	60	belong	23	6
36	ham	84	34	poke	75	10
42	alloy	73	34	stand	74	10
42	door	42	38	few	93	10
48	bacon	32	71	plot	54	11

bacon Series (doublets)

n	Strong		% C.	Weak		% C.
6 and 6	dirty	12, 50	31	cause	41, 87	1
9 and 9	cat	33, 96	18	lend	85, 99	2
12 and 12	radio	27, 93	24	cave	58, 76	2
15 and 15	piano	76, 23	16	bench	53, 64	4
18 and 18	sister	28, 71	36	fabric	27, 78	3
21 and 21	stop	67, 74	46	cable	47, 32	6
24 and 24	farmer	44, 67	35	locust	26, 72	10
24 and 24	plus	64, 47	35	bias	76, 47	10

angel Series

n	Strong		% C.	Weak		% C.
6	brown	90	29	deplore	82	0
6	hexagon	88	52	ease	79	0
12	cadet	16	71	basin	47	0
12	date	96	29	envy	94	0
12	prince	26	38	loose	84	0
24	act	10	71	mint	28	5

Number Number 644 Series

n	Strong		% C.	Weak		% C.
48	120	25	64	471	54	0
24 and 24	130	28, 54	44	263	81, 53	0
24 and 24	807	28, 47	50	346	76, 47	0
18 and 18	193	74, 93	25	805	94, 96	0
18 and 18	517	64, 28	19	386	27, 78	0
15 and 15	365	36, 27	25	137	55, 72	0
12 and 12	962	96, 26	16	347	58, 76	0
9 and 9	489	85, 99	38	146	40, 29	0

TABLE 72A

THE PERCENTS CORRECT FOR PAIRS IN THE *adopt* SERIES CHOSEN TO HAVE WORDS OF PLEASANT AND UNPLEASANT CONNOTATION, OR MEANINGFUL ASSOCIATIONS

Repetitions	Pair		% Correct	Repetitions	Pair		% Correct	Average of 4 Medians for Neutrals
3	love	40	44	3	pus	14	9½	
3	caress	95	4	3	entrails	97	9½	
3	kiss	60	40½	3	slimy	87	2½	
3	hug	84	10	3	vomit	21	23	4
6	vacation	52	33	6	greasy	51	18½	
6	admired	26	6½	6	cancer	54	18½	
6	riches	69	5	6	abscess	71	6	
6	success	78	5½	6	dandruff	86	30	6½
12	dance	35	39½	12	dirty	24	49½	
12	velvet	16	38	12	alone	49	23½	
12	turkey	44	46½	12	spider	58	15½	
12	rubies	67	14½	12	snake	76	24½	19
3	twins	22	66					
3	youth	16	33					
3	thirty	30	63½					
3	unlucky	13	82					

rette) belongs here. The effect of interest through personal contacts of a somewhat less strikingly pleasant or unpleasant sort appears in the great strengthening of connections with *sister*, *radio*, *piano*, *sedan*, *Dodge*, *gas*, *map*, *stop*, and probably *album*, *cat*, *diet*, and *dumb* (in the sense of stupid).

This leaves us with *Germany 66*, *lizard 16*, *city 95*, *mason 25*, *act 10*, *adverb 10*, *alloy 73*, *door 42*, *farmer 44* and *67*, *plus 64* and *47*, and *brown 90*. These are characterized by concreteness of the words and (to some extent) by ease of the numbers.

The numbers did not occur equally often in the *angel* and *bacon* experiments, and those numbers (such as *42* or *96*) which occurred very frequently would naturally be preferred somewhat in guessing. The effect of this makes our inferences less secure than they would otherwise be, but

the effect is not large, and probably few or none of the words listed as *strong* in Table 72 owe their listing to it.

The list of those pairs which were very slightly learned, though occurring 20 times or more, shows words very weak in interest by exciting quality or personal reference, and rather abstract in comparison with the list of those easily learned. It is: *plot 54, few 93, stand 74, poke 75, belong 23, hasten 73, locust 26* and *72, bias 76* and *47, cable 47* and *32, fabric 27* and *28, bench 53* and *64, mint 28, paste 75.*

CHAPTER V

The Influence of the Impressiveness of the First Term upon the Gain in Strength from a Given Number of Occurrences of the Connection

The concept of the strength or impressiveness of a situation or stimulus has been familiar to psychology. Intense sensory stimuli, for example, loud sounds, have been considered stronger or more impressive or more influential than less intense stimuli of the same sort. Stimuli that last a second have been considered more impressive than stimuli otherwise identical but lasting only a tenth of a second. Stimuli that are closely attended to have been considered more impressive than stimuli otherwise identical but not in the focus of attention. The concept has been somewhat vague, and we may leave it so for the present.

Our present concern is to inquire whether the impressiveness of a situation or first term exerts an influence upon the connection between it and its response or sequent second term. If, for example, $S_1 \longrightarrow R_1$ and $S_2 \longrightarrow R_2$ are repeated equally often with equally satisfying consequences, and if S_1 is equal to S_2 and R_1 is equal to R_2 in identifiability, availability, and all other respects save that S_1 is more impressive than S_2, will the connection $S_1 \longrightarrow R_1$ be strengthened more than the connection $S_2 \longrightarrow R_2$?

It will. We have experiments of two sorts to test and measure this influence of the impressiveness of a first term upon its connection with a second term. The experiments of the first sort are those in which impressive words like *love*, *kiss*, *insane*, *vomit*, are compared with relatively unimpressive words like *paste*, *crude*, *aim*, *neglect*, when series of word number pairs are presented. Not only will indi-

viduals remember much more easily that the series contained *love*, *kiss*, *insane*, and *vomit* than they will remember that it contained *paste*, *crude*, *aim*, and *neglect* (frequency being equal for the two groups); they will remember what numbers followed *kiss*, *vomit*, etc., far better than what numbers followed *paste*, *crude*, etc. The impressiveness of the first term adds potency to occurrences of the connection.

As was shown in Table 61, the percentages correct in the *adopt* series, when given to subjects of whom about 80 percent were women, were about twice as high for *love*, *caress*, *pus*, *entrails*, etc., as for neutral words of the same frequencies. In an experiment with a new series, the *force* series, in which about 95 percent of the subjects were men, the percentages correct for eight of these impressive words and for neutral words of equal frequency of occurrence were as follows for 78 subjects:*

beauty	39	12	occurrences,	28%	correct.
turkey	46	12	"	26	"
dinner	26	9	"	23	"
vacation	52	6	"	36	"
kiss	63	3	"	11	"
devil	96	12	"	55	"
dirty	24	12	"	31	"
insane	84	9	"	36	"
greasy	51	6	"	3	"
vomit	21	3	"	7	"

Average	for	12	occurrences,	35%	correct.
"	"	9	"	29%	"
"	"	6	"	19%	"
"	"	3	"	9%	"

Average	for	4	neutrals	of	12	occurrences,	27%	correct.
"	"	4	"	"	9	"	28%	"
"	"	4	"	"	6	"	10%	"

In our second set of experiments, the greater impressiveness of the first term was that due to repeating the word

* The numbers following the impressive words were changed in some cases from those in the *adopt* series, so as to have no multiples of 5 or repeated digits.

three times rather than once before presenting its number, thus: *marble marble marble 61.*

In the *force* series there were included the following:

marble marble marble 61 and *bag 32,* each fifteen times.
elm elm elm 46 and *chaos 33* and *porter 22,* each twelve times.
denote denote denote 18 and *alcove 34* and *rainbow 80,* each nine times.
bald bald bald 42, hook hook hook 59, debt debt debt 38, hazel 91 and *rely 99,* each six times.

With equal numbers of repetitions in a previous experiment the percents of right responses for *marble 61* and *bag 32* were 11 and 20, respectively. For *elm 46* and the average of *chaos 33* and *porter 22* they were 17.5 and 22.25. For *denote 18* and the average of *alcove 34* and *rainbow 80,* they were 4.5 and 18. For the average of *bald, hook,* and *debt* and the average of *hazel* and *rely,* they were 7.0 and 20.0, respectively.

The pairs with the first term repeated three times thus have a considerable handicap to overcome. They not only overcame it, but in general surpassed the control pairs. When the first terms were made impressive by repetition, the percents correct for the 78 subjects were: for 15 occurrences, 58; for 12 occurrences, 41; for 9 occurrences, 54; for 6 occurrences, 10. For the control pairs, the corresponding percents were 14, 28, 33, and 13.

The *force* series contained also certain pairs in which the number was spoken three times at each occurrence of the word, as *pavement 48 48 48, neutral 65 65 65. Pavement 48 48 48* occurred 15 times, *neutral 65 65 65* occurred 12 times, *remove 87 87 87* occurred 9 times, *nasal 69 69 69, chart 52 52 52,* and *outwit 29 29 29* occurred 6 times each. In a previous experiment *pavement 48, neutral 65,* etc., had been found to be, respectively, approximately equal in percentage of correct responses to *marble 61, elm 46,* etc., and

the two teams of six pairs were very closely equal as teams. *Pavement 48 48 48*, etc., have the advantage over *marble marble marble 61*, etc., that the listener can be thinking of *pavement* as he hears *48 48 48*, whereas he cannot so think of *61* as he hears *marble marble marble.* This advantage does not suffice to counterbalance the effect of the greater impressiveness of the first term upon connection-forming. For the 78 subjects of the experiments with the *force* series, there were 142 correct responses in the six cases where the word was repeated and only 81 in the six cases where the number was repeated.

It seems certain that the interest which attaches to the first term and makes it graspable and memorable extends its influence to the connection with the second term. This is important. *Candy, cigar, ham, bacon, devil, dirty,* and *garlic* are memorable words, but there is nothing intrinsically pleasant, unpleasant, exciting or interesting in having *candy* followed by *52* rather than any other number. Any attention-value which this connection has is derived as an effluence or radiation from *candy.* One possible explanation for such a spread is a general fact of physiology whereby the receptivity and alertness aroused by any event lasts longer than the event itself. Another possible explanation is that the *candy, cigar, bacon,* or the like causes a more energetic neural action than the less interesting *remove, belong,* or *poke* and makes a more energetic connection with whatever belonging sequent may follow it. Both of these explanations might be true.

As a means of differentiating between them we devised the following experiment: a series of pairs (the *force* series) is made in which a certain neutral pair always follows a pair whose first term is exciting or interesting. If the effect described above is due to a continuance of a general receptivity and alertness, the following pair should benefit somewhat therefrom. If, on the other hand, the effect is due wholly to the tendency of an energetic neural action to connect energetically with its belonging sequent,

the following pair should not benefit, since neither of its members "belongs to" the interesting first member.

Experiment 39

The experiments with the *force* series were conducted in the same general manner as those with the *adopt, bacon,* and *angel* series.

The instructions were as follows: "I shall read a long series of pairs of words and numbers like *bread 46, sing 92, ducat 58.* You need not try to remember them, but simply listen with a moderate degree of attention to them. The numbers will all be two-figure numbers, i.e., from 10 to 99."

The pairs were read monotonously at the rate of about $1\frac{1}{2}$ seconds per pair.

The series consisted of 10 words occurring twice each, as the first ten and last ten of the series, and of the following:

4	words,	30	occurrences	each,	scattered.
2	"	18	"	"	6 sequences of 3 each.
2	"	18	"	"	scattered.
1	word,	21	"	"	"
3	words,	24	"	"	"
3	"	24	"	"	distributed in sequences of 7, 4, about 20 pairs or 30 seconds later, 2, 2, 2, about 40 pairs apart, 1, 1, 1, 1, 1, 1, 1, about 100 pairs apart.

4	impressive words,	12	occurrences	each,	scattered.
3	" "	9	"	"	"
4	" "	6	"	"	"
4	" "	3	"	"	"

8 words of 21, 15, 12, 12, 9, 9, 6, and 6 occurrences, scattered, coming after impressive word pairs.

8 words of 21, 15, 12, 12, 9, 9, 6 and 6 occurrences, scattered, coming after weak or ordinary word pairs.

4 words of 6 occurrences in sequence, two following impressive word pairs and two following ordinary pairs.

6 words with 15, 12, 9, 6, 6, and 6 occurrences, scattered, the word being always repeated three times.

6 words with 15, 12, 9, 6, 6, and 6 occurrences, scattered, the number being always repeated three times.
8 words, 6 occurrences each, scattered.
4 " 6 " " two sequences of 3.
4 " 6 " " in sequence.
3 " used to fill out the series of 1052 occurrences.

The test as shown below was given immediately after the reading of the last pair.

Write after each word the number which came after it. If you do not remember which number came after it, write the first number that comes into your mind. Write some number after each word.

album
alcove
alder
also
answer

bag
bald
bead
beauty
chaos

chart
cherry
debt
denote
devil

dinner
dirty
elm
enjoy
favor

greasy
group
hasten
hazel
his

hook
insane
kiss
leafy
legal

lemon
marble
mason
nasal
neutral

outwit
pavement
picnic
ponder
porter

rainbow
relic
rely
remove
sandy

shellac
soft
turkey
vacation
vomit

drab
food
lucid

The *force* series contained ten pairs directly following *love 47, kiss 63, vomit 21, candy 52, vacation 52, greasy 51, cancer 54, dandruff 86, dinner 26, insane 85, turkey 46, dirty 24, devil 96, blond 68,* and *beauty 39* in the one case, and ten other pairs directly following *paste 75, crude 31, neglect*

64, plot 54, stand 74, and other pairs found to be weak or neutral in previous experiments. The pairs so placed were two groups chosen for equality in percentage correct in previous experiments. Thus *leafy 23*, which had 35 correct in a certain experiment as a result of 21 occurrences, is put after impressive word pairs, and *album 41* which had 36 correct under the same conditions is put after weak word pairs. *Group 53* and *bag 32*, with 18½ and 20 correct in a previous experiment, are the next choices, and so on for twenty word-number pairs, ten being used after impressive word pairs and ten, of equal previous percents correct, after weak word-pairs.

The potency of an impressive word like *kiss, love, cancer,* or *insane* does not extend beyond the number which follows it and belongs to it. For 78 subjects, the total number of correct responses for *leafy, group*, etc., which followed impressive pairs, is 137, whereas the total for *album, bag*, etc., which followed weak or ordinary word pairs, is 164. In two cases the pair following an impressive word pair shows a higher percent correct, in three cases there is equality, and in five cases it shows a lower percent correct.

From the experiment it appears (1) that impressiveness in the first member of a pair, whether attained by the quality of the word or by repeating it, increases the strength of the connection leading from it to its belonging sequent; (2) that impressiveness in the second member of a pair attained by repeating it increases the strength of the connection leading to it very much less; and (3) that the strengthening effect in the former case does not extend beyond the belonging sequent.

We have corroborated these conclusions by several additional experiments. The *force* series was read to 38 individuals. The percents correct for pairs containing the impressive words of 12, 9, 6, and 3 occurrences listed on page 132 were 31, 43, 18, and 25, and the percentages for those with the neutral words of 12, 9, and 6 occurrences were 34, 14, and 11. The percents correct for the pairs in which

the word was repeated three times were 74, 37, 26, and 23, whereas for pairs with somewhat more impressive words not repeated, they were 16, 29, 8, and 12, and for pairs with equally impressive words having the numbers repeated three times they were 42, 8, 5, and 12. The ten neutral pairs read immediately after the strong words had enough more correct responses than the ten read immediately after the weak pairs to make up the deficit shown by the 78 subjects. The totals for the 116 subjects are 211 correct after the impressive and 214 correct after the weaker.

Experiment 40

In a new series read to 118 subjects, *dinner 26* and *insane 84*, with nine occurrences, average 36 percent of correct responses, whereas *basal 83* and *divide 37*, with the same number of occurrences, showed only 10 percent. *Kiss 63* and *vomit 21* averaged 39 percent, while *logic 19, spiral 24, borax 32*, and *collect 91*, also with 3 occurrences, each averaged less than 5 percent. In this new series a set of 6 pairs in which the word was repeated three times was compared with a set of 6 pairs in which the number was repeated three times. The two sets were intrinsically otherwise equally impressive (*leafy, group, also, his, legal*, and *mason* versus *album, bag, chaos, porter, alcove*, and *rainbow*). The number of correct responses was 179 for the former and 123 for the latter.

Experiment 40a

Eighty individuals who were given instructions similar to those on page 135 listened to a short series (the *force* series) containing 12 repetitions of each of the following:

4 pairs with impressive first terms: *cigar 42, devil 96, insane 85*, and *vacation 52*.

3 pairs with weak first terms: *crude 31, hasten 73*, and *paste 75*.

2 pairs coming just after a pair with an impressive first term: *also 27* and *leafy 23*.

2 pairs coming just after a pair with a weak first term: *album 41* and *chaos 33*.

The series contained also 8 repetitions of each of the following: *denote denote denote 18, marble marble marble 61, pavement 48 48 48, remove 87 87 87, bag 32*, and *rainbow 80*.

It contained also 4 repetitions of each of the following: *force 27, space 16, ready 38, squint 81, apply 23, trunk 34, decent 40, captain 69.* It contained 3 repetitions of *belong 23, neglect 64, plot 54, poke 75, cable 47*; 2 repetitions of *twins 22*; and 1 each of *soft 53, rope 27*, and *esteem 68.*

As soon as the series had been read to the subjects, they were required to write the number that came after each of certain words in the series if they remembered what it was, and if they did not remember what it was to write the first number that came to mind. The words *album, apply, also, bag, chaos, cigar, crude, decent, denote, devil, hasten, insane, leafy, marble, paste, pavement, rainbow, ready, remove, vacation*, and *twins* were read at intervals of about two seconds.

The four pairs with impressive first members showed 60.6 percent of correct responses; the three with weak first members showed 18.3 percent of correct responses. *Denote denote denote 18* and *marble marble marble 61* showed 43.1 percent; *pavement 48 48 48* and *remove 87 87 87* showed 26.9 percent; *bag 32* and *rainbow 80* showed 36.3 percent. The two pairs following pairs with impressive first terms showed 30.6 percent of correct responses; the two pairs following pairs with weak first terms showed 18.8 percent of correct responses.

This same short *force* series was given in the same way to 44 other individuals, who, however, were less careful in following the instructions concerning the test and did not write a number for every word of the test. Theoretically,

we should in such cases add to the number correct slight corrections representing what would have been attained by chance if some number had always been written. But the empty spaces are so few that the effect of these corrections is almost negligible and I have not taken the time to make them.

The results from this group of 44 individuals are percentages of correct responses as follows:

Impressive 57.4, weak 10.6
w w w n 40.0, w n n n 28.4, w n 29.6*
After impressive 46.6, after weak 33.0.

Experiment 40b

It is instructive to repeat our experiments with impressive versus weak words, reversing the order within each pair. We have done this with the *force* series, adding one digit to every number so as to have the first members all different. We then have *391 beauty, 962 devil, 265 dinner, 843 insane*, etc., instead of *beauty 39, devil 96, dinner 26, insane 84*, etc. The results appear in Table 73.

The learning is much less than for the original *force* series. The total number of rights for the attentive group of 33 averages 6½ per person compared with 14 for a comparable group with the original *force* series.† This is presumably due in large measure to having the less impressive member first. The use of three-figure instead of two-figure numbers adds some difficulty but probably not much.

* Here and elsewhere we use w w w n to signify an occurrence with the word spoken three times followed by the number spoken once. Similarly for w n n n, w n, w n w n, etc.

† In this experiment the subjects were not required to write a word after every number in the test, but to write words after only such numbers as definitely suggested some word as their sequent in the reading. Moreover, in the case of 164 individuals, the time available for the test was shorter than in the experiments with the original *force* series. Consequently the results here are not strictly comparable with those of the original *force* series, the number of rights being less (but not much less) than it would have been with full time and opportunity for chance rights. However, the general weakness of connections between 3-place number and word as compared with connections between word and 2-place number is beyond question.

The impressiveness of the words adds strength to the connection, though not nearly so much as when the impressiveness lies in the first member of each belonging pair. In experiments with 234 subjects, half of whom were instructed to be just barely attentive enough to report that they heard each of the pairs, the other half being instructed to attend about as they would to a college lecture, the numbers of rights average 11¼ for *beauty, turkey, devil* and *dirty*, with 12 occurrences each, 16½ for *dinner* and *insane* with 9 occurrences each, 2 for *vacation* and *greasy* with 6 occurrences each, and 7 for *kiss* and *vomit* with 3 occurrences each. The averages for neutral words of like numbers of occurrences were, respectively, 10¾, 7, 4¼, and unknown. The words were *chaos, porter, also, his* (12 occurrences), *alcove, rainbow, legal, mason* (9 occurrences), *hazel, rely, alder, sandy* (6 occurrences).

If impressiveness is added by repetition, the impressiveness is very effective when added to the first member (now a three-place number), but does little or nothing when added to the second member (now a word). The total number of rights for the six pairs with repetition of the first member was 259; for six pairs with repetition of the second member the total was 50; for six average neutral pairs with the same numbers of occurrences as the set of strengthened pairs it was 35.

The ten pairs which immediately followed pairs containing *dinner, devil, kiss, vomit,* and other impressive words, were less often right in the test than the ten equally memorable pairs which immediately followed neutral or weak pairs. The totals were, respectively, 34 and 91.

Combining the results from all the experiments so far, we find the following comparable numbers of correct responses:

Pairs with impressive first members (like *cigar, vacation, devil, insane*) versus pairs occurring equally often with ordinary first members, 765 and 330.

Pairs with these impressive words as second members

TABLE 73

NUMBER OF RIGHT RESPONSES IN TESTS AFTER THE *force*-REVERSED SERIES

Impressive Words	Occurrences	Number of Right Responses A 33 Att.	B 37 Inatt.	C 94 Scoring 2 or More	D 70 Scoring 1 or 0
379 picnic	28	3	3	4	1
391 beauty	12	1	0	6	0
469 turkey	12	2	0	4	0
265 dinner	9	6	1	11	1
523 vacation	6	1	1	1	0
631 kiss	3	1	2	6	0
967 lemon	28	15	8	16	2
962 devil	12	2	3	8	0
247 dirty	12	4	1	13	0
843 insane	9	0	1	13	0
517 greasy	6	0	0	1	0
219 vomit	3	0	2	3	0

Neutral or weak words following pairs containing strong words.

	Occurrences	A	B	C	D
238 leafy	21	1	4	2	0
532 group	15	1	0	0	0
271 also	12	1	0	10	2
556 his	12	1	0	1	0
512 legal	9	0	1	0	0
254 mason	9	1	0	1	0
279 alder	6	0	0	0	0
218 sandy	6	1	3	1	0
498 drab	6s	0	0	1	0
813 shellac	6s	0	0	1	0

Neutral or weak words following pairs containing weak or neutral words.

	Occurrences	A	B	C	D
418 album	21	4	1	1	0
327 bag	15	1	2	0	0
331 chaos	12	13	5	11	0
226 porter	12	2	2	3	1
348 alcove	9	2	1	0	1
809 rainbow	9	6	4	11	0
916 hazel	6	0	0	4	0
991 rely	6	6	1	1	0
261 bead	6s	1	0	0	0
891 enjoy	6s	0	1	6	0

TABLE 73 (*Continued*)

Pairs with first member strengthened by 3 repetitions of the number.

	Occur-rences	A	B	C	D
613 marble	15	24	17	71	18
467 elm	12	13	8	35	2
186 denote	9	7	2	31	0
427 bald	6	5	2	11	0
596 hook	6	0	2	2	0
385 debt	6	2	1	5	0

Pairs with second members strengthened by 3 repetitions of the word.

	Occur-rences	A	B	C	D
483 pavement	15	4	2	8	1
652 neutral	12	4	1	3	0
871 remove	9	4	2	7	2
293 chart	6	1	0	3	0
528 nasal	6	0	1	0	0
691 outwit	6	1	1	5	0

versus pairs occurring equally often with ordinary words as second members, 83 and 66.

Pairs with first members repeated three times versus pairs with slightly more impressive first terms unrepeated. When word is first, 324 and 206. When number is first, 257 and 35. For both, 581 and 241.

Pairs with first members repeated three times versus pairs with second members repeated three times. When word is first, 503 and 308. When number is first, 257 and 50. For both, 760 and 358.

Pairs following pairs with impressive first members versus pairs following pairs with weak or ordinary first members, 335 and 365.

In still another experiment *kiss 63* and *vomit 21*, occurring three times each, were responded to correctly 37 and 20 times, whereas the average for *logic 19*, *spiral 24*, *borax 32*, and *collect 91* was 3¾. *Dinner 26* and *insane 84* showed 29 and 36 correct responses, whereas *basal 83* and *divide 37* showed 7 and 15 correct. (All four pairs occurred 9 times each.)

The very great influence upon the connection of impressiveness in the first member and the very slight influence of impressiveness in the second member, and the failure of the influence to extend beyond the belonging sequent, are thus established for this sort of learning. These facts are important for both theory and practice. They furnish strong support for an associational or connectional mental dynamics as opposed to such a dynamics as the Gestalt psychologists seem to advocate, since the first half of the belonging sequence behaves so differently from the second half. They suggest that the strength of a connection may, in general, be a function of the impressiveness of the first member as well as of qualities of the connection itself.

In the practice of learning vocabularies, tables, dates, names, and the like, they suggest that instead of giving equal emphasis to the two members, or an excess emphasis to the second as is now commonly done, it may be profitable to emphasize the first member. In more elaborate learning of facts in answer to questions, more emphasis upon the questions may be profitable.

We have made two experiments to explore the range of application of this law of the influence of the impressiveness of the first term upon the strength of the connection leading from it. In Experiment 41 we used French words and their English equivalents. In Experiment 41a we used events and their dates, terms and their definitions, and the like. The method of presentation was in series like the *adopt* and *force* series described above.

Experiment 41

Half the group were instructed to be just barely attentive enough to be able to say honestly that they had heard every word. The other half were asked to attend moderately without special effort, about as they would to a lecture or sermon. The average numbers correct were as follows (F = a French word; E = its English equivalent):

12 occurrences	of F E,	Inattentive,	7½,	Attentive,	12½
12 "	of F F F E,	"	19	"	30
12 "	of F E E E,	"	15	"	20
12 "	of FE FE FE,	"	20	"	28
6 "	of F E,	"	2½	"	5½
6 "	of F F F E,	"	6	"	13
6 "	of F E E E,	"	9½	"	14
6 "	of FE FE FE,	"	22	"	29

The sums are: F E, 28; F F F E, 68; F E E E, 58½; FE FE FE, 99.

These results are inconclusive. On the whole F F F E seems much better than F E, and better than F E E E, but the averages are not very reliable, some pairs like *acajou-mahogany, babiche-lap-dog* and *bavette-bib* showing scores four to seven times as high as others of equal frequency of occurrence and similar form of repetition, for example, *fausset-peg, émoudre-sharpen* and *drêche-malt.*

Experiment 41a

The material used is shown by the following sample:

1. (1) The percentage of children continuing to grade 9 or later, the percentage of children continuing to grade 9 or later, the percentage of children continuing to grade 9 or later (2) is about 40.
2. (1) Within a school grade the children attaining the highest scores in tests of educational achievement will be the (2) youngest, youngest, youngest.
3. (1) The cost of education per capita of total population varies in the different states (2) from about $4 to about $25. (1) The cost of education per capita of total population varies in the different states (2) from about $4 to about $25.

In the test, the parts marked (1) above were read once and the parts marked (2) above or some adequate equivalents were to be supplied by the subjects of the experiment.

The results for the various sorts of presentation were as follows, in percents correct:

(1) (2) occurring	once,	Inattentive,	47,	Attentive,	58
" "	twice,	"	34,	"	61
" "	three times,	"	23,	"	51
" "	four times,	"	64,	"	91
(1) (2) (1) (2) occurring	once,	Inattentive,	34,	Attentive,	58
" "	twice,	"	42,	"	78
(1) (1) (1) (2) "	once,	"	22,	"	46
" "	twice,	"	36,	"	56
(1) (2) (2) (2) "	once,	"	29,	"	49
" "	twice,	"	29,	"	54

The probable errors of these determinations are very large (from .10 to .30) but are deceptive, since the harder tasks were somewhat equally divided among the various types of presentation. However, it is clear that many more experiments must be made, since the results from 1, 2, and 3 repetitions of the (1) (2) type are here in reverse order to what an adequate random sampling would give.

Taking the figures at their face value provisionally, the (1) (1) (1) (2) type is as effective as the (1) (2) (2) (2) type. The differences are —.07, +.07, —.03, and +.02, averaging .00.

Combining the inattentive and attentive groups and comparing the easiest task of the (1) (1) (1) (2) sort with the easiest task of the (1) (2) (2) (2) sort and so on, we have, for the four single occurrences, differences of —.06, —.05, +.04, and —.13. For the four occurring twice, we have +.13, +.30, —.20, and —.05. The average of .00 has a probable error of ± .04.

The (1) (1) (1) (2) is not nearly so effective as (1) (2) (1) (2), the differences here being —.12, —.06, —.12, and —.22, averaging —.13. Its probable error computed as just shown for the (1 1 1 2)—(1 2 2 2) difference is ± .04½.

It is remarkable that, even with these pairs whose first parts would seem to be entirely comprehensible to the adult students of education who served as subjects in the experi-

ment, and also to be sufficiently impressive in one reading to give all that memory needed of the first term, three repetitions of the (1) and one of the (2) did as well as one of the (1) and three of the (2). Certainly nobody would ever have prophesied that repeating the first parts would be as effective as repeating the second parts.

Many and varied experiments must be performed before one asserts the generality of the principle that adding impressiveness to the first member, whatever it may be, results in the addition of strength to whatever connections it makes.

In any case, the adjustment of additions of impressiveness to the first and second members so as to make the most economical use of time and effort is a fundamental problem in the management and facilitation of learning; and the almost universal custom of favoring the second member becomes very questionable.

CHAPTER VI

The Influence of the Distribution of the Occurrences of a Connection upon Its Strength

There has been much experimentation concerning the influence of the distribution of practice in learning codes, collections of facts, acts of skill, etc. There have, however, been no experiments in which the influence of various distributions in time upon the formation of a single connection has been measured directly.

The method used in the *adopt* and *force* series permits one to do this, and has the additional feature that one knows what the intervening times are filled with, and that they are all filled with the same sort of activity. We have so far obtained only a small amount of information on distribution, valuable chiefly to illustrate the method.

In the *adopt* series (see Table 61), 3 and 6 occurrences produced notably greater strength when in sequence than when scattered over an hour; 9 occurrences were somewhat better when in sequence; 12 occurrences produced rather greater results when scattered.

In the *Number Number* series, 12 occurrences in two sequences of 6 each produced greater strength than 12 scattered (8 to 2 for the 8 subjects). Eight pairs with 6 occurrences each were used in the *bacon* series and also in the *force* series. Four of them were given in sequence in the *bacon* series and scattered in the *force* series. The average percent correct was 13½ for these pairs when in sequences and 8 when scattered.

In the *bacon* series there were also twelve pairs occurring 6 times each, eight in sequence and four scattered. The average percent correct was 15 for the former and 6½ for the latter.

In the *force* series, *bead* and *enjoy* were read 6 times each in sequence; *alder* and *sandy* were read 6 times distributed over the series. The numbers correct for 116 individuals were 3 and 7 for those in sequence, and 8 and 12 for those distributed. In a modification of the *force* series, *alder* and *sandy* were read 6 times each in sequence, while *bead* and *enjoy* were read 6 times distributed over the series. The numbers correct for 118 individuals were then 4 and 10 for those in sequence, and 8 and 1 for those distributed. The same words then give scores of 24 in sequences and 29 when distributed.

In an experiment with a still different series, 6 occurrences in sequences for *alder 27, sandy 21, drab 49* and *shellac 61* resulted in 49 correct responses while 6 separate occurrences for *hazel 91, rely 99, bead 26,* and *enjoy 89* resulted in 68. The results by separate groups are:

1.	28 inattentive;	sequences,	9;	separate,	9
2A.	44 attentive;	"	16	"	17
2I.	46 inattentive;	"	9	"	12
3L.	35 low scoring;	"	3	"	8
3H.	34 high scoring;	"	12	"	22

Up to 6 occurrences, concentration is better than distribution. The advantage in concentration in these experiments may lie in more physiological summation, or in enabling the subject to make anticipatory reactions from within and to be pleased thereby, or in increasing attention to the pair, or possibly in other ways.

The probable advantage of forming a connection firmly enough at its first appearance to enable it to resist the influence of time and interfering connections until its next appearance has been recognized since Jost's early work. In the case of the ordinary units of learning, as in schools, the advantage seems fairly certain.*

* Subject to certain special amendments, such as the recognition of the desirability in some cases of a first brief acquaintance serving to give a general sense of familiarity and hopefulness concerning the learning, and of the desirability in some cases of specially thorough learning of something at the start as a means of understanding something else.

There is also rather general agreement that in the case of ordinary units of learning the amount of repetition should decrease and the length of the intervals increase until the two are respectively as small and as long as will maintain the ability.

In the case of single connections learned by repetition alone or with a minimum of chance for the law of effect to operate and with all the time intervals very short, such an arrangement still seems preferable.

In the *force* series three pairs, *answer 63, ponder 73*, and *favor 81*, each with 24 occurrences in all, were distributed as follows: 7 occurrences in sequence, an interval filled by approximately 15 other pairs; 4 occurrences in sequence, an interval filled by approximately 32 other pairs; 2 occurrences in sequence, an interval filled by approximately 48 other pairs; 2 occurrences in sequence, an interval filled by about 85 other pairs; 2 occurrences in sequence, and thereafter single occurrences at long intervals to make up the 24. Three other pairs of equivalent "impressiveness" according to earlier experiments—*cherry 36, soft 53*, and *hasten 73*—were distributed in 24 single occurrences each.

In one group of 78 individuals the percents correct were 28, 26, and 19 for the three former and 51, 23, and 22 for the three latter.*

In another group of 38 individuals, the percents correct were 15, 12, and 2 for the former and 15, 13, and 10 for the latter.

When *cherry 36, soft 53*, and *hasten 43* occur 24 times by the 7, 4, 2, 2 plan, and *answer 63, ponder 73*, and *favor 81* occur 24 times by the 1, 1, 1, 1 plan, the results are:

1.	Inattentive	7, 4, 2, 2 plan	25	1, 1, 1, 1 plan	19
2A.	Attentive	"	46	"	27
2I.	Inattentive	"	41	"	21
3L.	Low scoring	"	34	"	15
4H.	High scoring	"	50	"	25
Total			196		107

* By reason of a local slang usage, *cherry* was a specially strong word for many in this group.

In an experiment in which the series consisted of pairs of 3-place numbers and words in that order, *635 answer, 731 ponder*, and *814 favor*, occurring 24 times each, were distributed by the 7, 4, 2, 2, 2, 1, 1, 1, 1, 1, 1, 1 plan, and *367 cherry, 538 soft*, and *739 hasten* occurred 24 times each, scattered somewhat evenly through the series. There was no demonstrable difference in the numbers right in the test, the former totaling 49, and the latter 55.

In an experiment with a modification of the *force* series, *cherry 36, soft 53*, and *hasten 43* had 24 occurrences each distributed 7, 4, 2, 2, 2, 1, 1, 1, 1, 1, 1, 1. *Answer 63, ponder 73*, and *favor 81* had 24 occurrences distributed 1, 1, 1, 1, 1, 1, etc. The 118 subjects had 75, 25, and 14 correct for *cherry, soft*, and *hasten*, and 53, 7, and 7 right for *answer, ponder*, and *favor*.

On the whole there is probably a slight advantage in favor of the distribution by the 7, 4, 2, 2, 2, 1, 1, 1, 1, 1, 1, 1 plan. The totals correct for it and for the 1, 1, 1 plan were 151 and 189 when the *answer, ponder*, and *favor* pairs were by 7, 4, 2, etc., and 114 and 67 when the *cherry, soft*, and *hasten* pairs were by 7, 4, 2, etc. If we multiply the latter results by 1.88 to give them equal weight with the former, and add, we have 365 and 315 as results by 7, 4, 2, etc., and by 1, 1, 1, 1, etc., respectively.

CHAPTER VII

The Polarity of Mental Connections

Everybody knows that it is much easier to say any familiar sentence or paragraph, such as the Lord's prayer, forward than backwards, and that a musician who would try to sing or play a piece backward would have to learn to do so almost *de novo*. In such cases each word or note is a response to the preceding word or note plus more or less of a general set left by the task and the completed fraction of it.

In shorter series, such as "A lives at 427 Spruce Street, Springfield, Ohio," or "German *genug*=English *enough*," the same principle holds: that connections operate best in the way in which they have been formed, or, in other words, that the way to secure a certain idea or feeling or act is to provide the situation to which it has been connected as a belonging sequent. The difference in favor of reconstruction of the total by being given its temporally first member or members is still substantial, though less striking.

Thought and conduct move from one term or state or process to another; the repetition or reward of a step from A to B may make that step more likely or easier or quicker, but without any corresponding influence upon the step from B to A. Sometimes the so-called backward association is almost or quite zero, for example, in many acts of skill. No matter how many times a man has served in tennis he will be at a loss if you ask him to divide his act in serving into four quarters and to make the last quarter first, then the third and then the second. His movements will be a caricature of the quarters of his real serve. He can make the real second quarter of it only by making the first quarter.

Sometimes the so-called backward association is a misnomer. Thus the reason why I can say my telephone number backward by syllables "jay five oh eight skill peek" is probably not because Peekskill 805 J has formed any backward connections but because I can hold all of it in mind at one time, and know already that J is the last syllable in it, and can quickly dismember it, beginning at either end, and so can give the syllables in reverse order, or alternately, or repeat them so as to form the arithmetical sequence "Peek skill skill 888 0000 55555 JJJJJJ," or otherwise arrange them.

It is, however, possible in some such cases that genuine associations are formed leading from second member to first, from third member to second and to first, and so on. The thought of *Peek* may not vanish before the thought of *skill* and *8* appear, *Peek* may still be echoing in the mind during and after their advent, so that though the main sequences are *Peek—skill* and *Peekskill—8, Skill—Peek* and *8—Peekskill* may be minor and weaker sequences. They are not backward associations, however. And they would be so weak in belongingness and, in general, so useless that we should expect them to be little if at all strengthened by repetition.

In Cason's experiments ['26] the memorizing of series apparently resulted exclusively in the strengthening of the specific connections A⟶B, B⟶C, C⟶D, D⟶E, etc. B⟶A, C⟶B, etc., showed no signs of any change.

It is also obvious that *Peekskill* has a certain unity or all-or-none quality which *5J* lacks; that in *fifteen, sixteen, seventeen, fifteen* has a unity which *teen six* lacks. *Teen six* is a pair of fragments wrested from two units. Ask a hundred people what number comes after *ven* and their responses will be much slower than if you ask them what number comes after *ten.* Their delay is partly due to certain specific habits, but it is also partly due to the fact that the *ven* of seven and eleven is a fragment with little associative potency of its own. Until we place it at the end

of seven or eleven it is unproductive. *Alphabetical* is a unity in a sense or to a degree that sharpshooter is not; but *sharpshooter* is more of a unity than *seven plus two* is; and that is more of a unity than *bay gum cry* is.

When a thought or act has such unity that it comes absolutely all or none, *in toto* or not at all, connections leading to it must perforce be to all of it; connections leading from it must perforce be due to the first half of it as much as to the second, if indeed we can speak of it as having halves; and connections within it there cannot be.

In features of thought or feeling or action which are unified to a high degree, though not perfectly, any part of the total may reinstate the balance, the last half evoking the first half nearly as well as the first evokes the last.

But if there is a first and a last at all, the forward connection will be stronger, other things being equal, than the backward. Such at least is the conclusion which we reach from previous experiments and from Experiment 42.

Experiment 42

In our experiment we used two degrees of unity, the moderate degree found in foreign and vernacular phrases like *raison d'être, ohne Hast, ohne Rast, exeunt omnes, sunt lacrimae rerum, facile descensus, obiter dicta, quot homines tot sententiae, de mortuis nil nisi bonum,* which always or almost always come as totals or not at all, and the high degree found in single words such as *calendar, obelisk, penguin, taciturn, chutney, clarinet,* and *rogue.* In choosing these words we took those in which the first half and second half seemed equally contributory to an understanding of the word, and equally likely to be the first (or last) half of other words. So, for example, we avoided words made out of recognizable roots and affixes.

We then made completion tasks by omitting from the beginning and from the end of the phrase or word, as shown below.*

* For the convenience of both critics and experimenters in this field, we present the lists in detail in Appendix III.

1. exeunt ________
2. haec olim ________ ________
3. materia ________
4. sunt lacrimae ________
5. facile ________
6. obiter ________
7. varium et mutabile ________ ________
8. suppressio veri ________ ________
9. experimentum ________
10. quorum pars ________ ________

1. ________ ________ la crême
2. ________ omnia solvit
3. ________ ________ literatim
4. ________ accompli
5. ________ aller
6. ________ ________ disce omnes
7. ________ macabre
8. ________ ________ ________ tamen usque recurret
9. ________ membra
10. ________ asinorum

aby..	camou.....	emph....	gend....	paja...
baci....	accom.....	pana...	samu...	airp....

....uito	....atis	....aulin	...izon	.....lesce
...olu	....itar	...cher	....aden	...icot

These tasks were given to some individuals with time limits and to others with no time limits, as described in the instructions below.* In the case of the phrases the time limit was practically inoperative, since the individuals reported that they would have been unable to add to their completions with added time.

Instructions for Giving a Test in Completing Familiar Quotations from Foreign Languages as a Speed Test

There are eight sheets divided into two sets. The first set has Nos. 1 to 50, the second has 51 to 100. Any one indi-

* Minor deviations from the quotations in the way of spelling were given full or partial credit. Except for proper names, any real English word was accepted in the case of the word-completions. Other reasonable rules were made to facilitate the scoring. Any set of rules will do if it is impartial in its treatment of additions at the beginning and at the end.

vidual should have only one set. Of the individuals having any one set, some should do first the completions where the printed word comes first, and others should do the completions where the printed word comes last. Instructions here will be for those having the printed words first. For those who have the printed word last, the only difference will be in the order of the distribution of the sheets. Give each person two sheets containing Nos. 1 to 50 (or 51 to 100), placing them face down. Say, "These sheets contain a list of more or less familiar quotations, from foreign languages mostly, with some words omitted. You are to write words on the lines to complete the familiar phrase, proverb, etc. Write one word for each inch of line. You will have 12½ minutes, as this is a speed test. First go through the entire list doing all that you can in the time allotted. Make your writing very clear. Write your name and the date on the back of each sheet now. When I say 'Go' turn them over and begin work at once. Be sure to write plainly." At the end of the allotted time say "Stop!" and collect all the papers quickly. Then give out sheets 1 to 50 (or 51 to 100) on which the printed words come last. Say, "We shall do this just exactly as before," and then read the directions given above.

Instructions for Giving the Above Test Not as a Speed Test

Distribute the papers face up. Say, "You are to write words on each line to complete the familiar phrase, proverb, etc., on this sheet. Write one word for each inch of line. First go through the entire list doing all that you are sure of. Then do as many of the others as you can, marking with an '*x*' any that you think you would not succeed in no matter how long you tried. Make your writing very clear. You need not hurry. This is not a speed test, but I do not wish to take more than a reasonable amount of your time. If you do not think of the proper completion in a half minute, just let it go. When you have done all that you can, please bring your papers to me."

Instructions for Experiments in Supplying Missing Letters at the Beginning and at the End of Words

In this experiment, we can use for any group two or four of the eight sheets. The same individual can do tasks 1 to 80 or tasks 81 to 160, or he can do one-half of 1 to 80 or one-half of 81 to 160. The same individual should not do any beyond

No. 80 if he does 1 to 80, or any before No. 81 if he does 81 to 160. The test may be given as a speed test or with abundant time. If given as a speed test, distribute to each individual one sheet, for example, A 1 to 40 or B 1 to 40, face down and say, "When I give the signal to go, please turn over this sheet and supply the missing letters to make complete words. For example, if you see *bre..* will you write *ad* or *ak* or any other two letters to make a complete word. If you see *...ses* you can write *hou* or *hor* or *pau*. Write one letter for each dot. Make your letters very clear. First go through the whole page making those completions which you can make at once. Then go back and do as many more as you can in the time allotted. Write your name and the date now on the blank side of the sheet and be ready to turn it over and begin work when I say 'Go!'" Then say, "Go!" and at the end of the allotted time say, "Stop!" and collect all the papers. With some groups you will use first the sheets with the printed letters first, that is, those marked "A"; with other groups, you will use first the sheets where the printed letters come last, that is, those marked "B." When the first sheet given out is collected, you will proceed with the second sheet, saying, "We will do this in just the same way as before" and repeating the instructions above.

The facts are reported in Tables 74 and 75.

The first half evokes the second half much oftener than the second evokes the first. Whether our phrases and words are fair samples may be left to the reader to decide. We tried to make them so. The result can be checked by

Table 74

Scores in completing quotations when words are omitted at the end and at the beginning

In Groups A and B, 12½ minutes were allowed for each set of fifty. In Groups C and D, there was no time limit

Set	Forward: Omissions at the End		Backward: Omissions at the Beginning		$\frac{\text{Forward}}{\text{Backward}} \times 100$
exeunt	A. 14 adults	133	B. 14 adults	77	
bis dat	B. "	56	A. "	47	
	A + B	189	A + B	124	152
exeunt	C. 13 adults	132	D. 13 adults	76	
bis dat	D. "	77	C. "	45	
	C + D	209	C + D	121	173

TABLE 75

SCORES IN COMPLETING WORDS WHEN LETTERS ARE OMITTED AT THE END AND AT THE BEGINNING

In groups M to R, 5 minutes are allowed for each set of 40 completions. In groups S and T, there was practically no time limit, 10 to 15 minutes being allowed for each 40 completions

	Forward: Omissions at the End				Backward. Omissions at the Beginning				Forward/Backward ×100	
	Group	No.	Correct	Wrong	Group	No.	Correct	Wrong	Correct	All
abyss	M	35	1334	450	N	48	839	303		
bewilder	O	38	1226	375	P	49	769	257		
Total			2560	825			1608	560	160	156
abyss	Q	37	685	90	R	33	516	60		
mosquito	R	33	633	90	Q	37	374	50		
bewilder	Q	37	670	96	R	33	475	73		
marjoram	R	33	642	127	Q	37	335	40		
Total			2630	403			1700	223	155	158
abyss	S	8	246	25	T	10	177	7		
mosquito	T	10	212	25	S	8	160	21		
bewilder	S	8	238	31	T	10	186	13		
marjoram	T	10	210	20	S	8	155	21		
Total			906	101			678	62	134	136

using other words, musical phrases, chemical formulas, algebraic formulas, firm names like Collins and Aikman, Smith and Wesson, Rogers Peet, Sears Roebuck, and other units or near-units in which the two halves are on the average equally important and contributory.

In view of these facts the tendency amongst psychologists of the Gestalt school to treat most or all of the constituents of perceptions and thought as totals which are unitary in mystical ways, being unified by inner forces above and beyond the ordinary laws of connection-forming, seems dangerous. And the tendency amongst many psychologists to retreat to vague and weak assertions about association, such as that a part of a mental fact may evoke the whole of it or that things which have been put together in the mind will tend to go together thereafter, seems ill-advised. The polarity or unidirectional quality of mental connections is a more reasonable hypothesis to-day than ever before.

CHAPTER VIII

THE INFLUENCE OF REPETITION OF A SERIES UPON THE OMISSION OF ITS INTERMEDIATE TERMS*

FROM time to time some student of behavior advocates or assumes the doctrine that the frequent occurrence of a series of physiological or psychological events (call it $A \longrightarrow B \longrightarrow C \longrightarrow D \longrightarrow E$) will tend to cause the omission of one or more of the intermediate terms, so that in the end $A \longrightarrow B \longrightarrow C \longrightarrow D \longrightarrow E$ tends to be replaced by $A \longrightarrow E$. Thus Jennings writes: "When a certain physiological state has been resolved, through the continued action of an external agent, or otherwise, into a second physiological state, this resolution becomes easier, so that in course of time it takes place quickly and spontaneously" ['06, p. 289]. "The law may be expressed briefly as follows: The resolution of one physiological state into another becomes easier and more rapid after it has taken place a number of times. Hence the behavior primarily characteristic for the second state comes to follow immediately upon the first state. The operations of this law are, of course, seen on a vast scale in higher organisms in the phenomena which we commonly call memory, association, habit formation, and learning." ['06, p. 291.] This law may be expressed conveniently as a tendency of a series of states

$$A \longrightarrow B \longrightarrow C \longrightarrow D$$

to become

$$A \longrightarrow D$$

or

$$A \longrightarrow B^1 \longrightarrow C^1 \longrightarrow D,$$

B^1 and C^1 being states B and C passed rapidly and in a

* Parts of this chapter are quoted from an article in the *American Journal of Psychology* (vol. 41, 1929, pp. 637-39) by Karl M. Dallenbach, Albert D. Freiberg, and Edward L. Thorndike.

modified way so that they do not result in a reaction but are resolved directly into D.

H. L. Hollingworth writes, in his explanation of how false responses are eliminated and the correct response is selected, "With repetition . . . these intermediate acts drop out" ['28, p. 214]. Hollingworth seems to attach a certain potency to the firstness of the first member of the series as well as to the repetition of the series. The end member, according to him, tends to be produced by that one of the preceding members "which first or unfailingly occurs" ['28, p. 216]. "The one which first and always occurs (hunger pang plus sight of food) will at once instigate the consequent (pulling the catch)" ['28, p. 214].

I quote the general objections to this doctrine which I stated a score of years ago.

> "If Professor Jennings had applied to this law the same rigorous analysis which he has so successfully employed elsewhere, he would have found that it could be potent to cause learning only if supplemented by the law of effect and then only for a fraction of learning.
>
> "For, the situations being the same, the state A cannot produce, at one time, now B and, at another time, abbreviated rudimentary B^1 instead of B. If A with S produces B once, it must always. If D or a rudimentary B^1 is produced, there must be something other than A; A must itself have changed. Something must have been added to or subtracted from it. In Professor Jennings' own words, 'Since the external conditions have not changed, the animal itself must have changed' ['06, p. 286]. And in adaptive learning something related to the results of the $S \longrightarrow A$ connection must have changed it.
>
> "The series $A \longrightarrow B \longrightarrow C \longrightarrow D$ does not become the series $A \longrightarrow D$ or $A \longrightarrow B^1 \longrightarrow C^1 \longrightarrow D$ by magic. If B and C are weakened and D is strengthened as sequents of A in response to S, it is because something other than repetition acts upon them. Repetition alone could not blow hot for D and cold for B.
>
> "Moreover, as a mere matter of fact, 'the resolution of one physiological state into another' through intermediate states does not with enough repetition 'become easier so that in course of time it takes place quickly and spontaneously.'
>
> "Paramecium does not change its response to, say, an obstacle

in the water, from swimming backward, turning to one side and swimming forward by abbreviating and eventually omitting the turn and the backward movement. The schoolboy does not tend to count 1, 2, 10, or to say a, b, z, or give ablative plurals after nominative singulars.

"Repetition of a series of physiological states in and of itself, on the contrary, makes an animal increasingly more likely to maintain the series in toto. It is hard to give the first and then the last word of an oft repeated passage like Hamlet's soliloquy or the Lord's Prayer, or to make readily the first and then the last movement of writing a name or address. Repetition never eliminates absolutely and eliminates relatively the less often or less emphatically connected.

"Even if supplemented by the law of effect, so that some force is at hand to change the effect of S upon the animal to A⟶D instead of the original A⟶B⟶C⟶D, the law of the resolution of physiological states would be relevant to only a fraction of learning. For example, let a cat or dog be given an ordinary discrimination experiment, but so modified that, whether the animal responds by the 'right' or the 'wrong' act, he is removed immediately after the reward or punishment. That is the event is either S⟶R1 or S⟶R2, never S⟶R1⟶R2. Let the experiment be repeated at intervals so long that the physiological state, state R1, or state R2, leading to the response R1 or R2 in the last trial, has ceased before the next. The animal will come to respond to S by R2 only, though R2 has never been reached by the 'resolution' of S⟶R1⟶R2.

"Cats in jumping for birds or mice, men in playing billiards, tennis or golf, and many other animals in many other kinds of behavior, often learn as the dog must in this experiment. The situation on different occasions is followed by different responses, but by only one per occasion. Professor Jennings was misled by treating as general the special case where the situation itself includes a condition of discomfort terminable only by a 'successful' response or by the animal's exhaustion or death" [Thorndike, '11, p. 267 f.].

With the coöperation of Dr. Karl M. Dallenbach and Mr. Albert D. Freiberg, we have secured detailed evidence of the failure of an oft-repeated series to be shortened by the omission of its intermediate terms. The evidence is found by an examination of the mistakes made by the compositors of 1068 galleys of the *American Journal of Psychology*,

comprising the years 1923-1927, inclusive. The action of a compositor in setting the type for a word—whether by hand, monotype machine, or linotype machine—is a fairly typical case of such a series of events. The sight of the word in the copy or the thought of it in memory is the first term or A, the movements of taking and setting the type from the proper compartments or pressing the proper keys are the B, C, D, etc., the last terms of the series being the setting of the last letter.*

If frequency of occurrence of such series tends to shorten the series by the omission of terms between the sight or thought of the word and the setting of its last letter, omissions of letters (1) should be much more common than additions, (2) should occur much oftener for intermediate letters than for final letters, and (3) should (other things being equal) be more common in words often set than in words rarely set. The compositor would, for example, have strong tendencies to set *te* for *the*, and *tht* or *tat* for *that*. These would have to be counteracted by other forces; and if the compositor's control broke down at all, so that he made mistakes of any sort other than those of ignorance, these tendencies should appear.

In the material which we have examined there are 373 cases where a word has a letter or letters omitted, and 324 cases where a word has a letter incorrectly repeated or a letter or letters added. The omissions do not come in intermediate positions more often than chance would prescribe, but very much less often. Sixteen of them are at the beginning of a word; 158 of them are at the end of a word; 209 of them are in intermediate positions. If we set the average length of the words for which letters were omitted as approximately 9, occurrences at the end of a word are, per opportunity, about five times as frequent as in intermediate positions. The omissions of intermediate letters do not occur very often in words which have been very fre-

* Sometimes, of course, the series is only a part of a word, and sometimes it includes more than one word.

quently used. On the contrary, as the list below for 1923 and 1924 shows, they are more frequent per opportunity in rare words.

Gedäch(*t*)nis
tur(*c*)ica; deficienc(*i*)es
intense(*l*)y
sugge(*s*)tion; as(*s*)umptions
non-substan(*t*)ial; i(*rr*)educible
gro(*s*)grain
pos(*i*)tions; cond(*i*)tioned
suc(*c*)eeded; fulfil(*l*)ing
material(*i*)zations; qualit(*at*)ive
occur(*r*)ing
Marse(*i*)llaise; quanti(*ta*)tive
decide(*d*)ly
direct(*ed*)ness
indiffer(*e*)ntly; hyg(*i*)enic
sla(*c*)ken; occur(*r*)ence
withdraw(*a*)l
psy(*c*)hological; decide(*d*)ly
equal(*iz*)ing
zusammenges(*e*)tzten
criti(*s*)ma
Ges(*t*)alt
gen(*e*)tic; invol(*v*)ed; sy(*s*)tem
nervo(*u*)s
fulfil(*l*)s; i(*n*)asmuch; moral(*i*)ty
conscien(*c*)e; criti(*ci*)zed
abstra(*c*)tions
mor(*t*)ality; actu(*a*)rial
diffi(*c*)ult; implicit(*l*)y
explicit(*l*)y; indescri(*b*)able
intermitten(*t*)ly
embarras(*s*)ment
vari(*a*)ble
adapt(*a*)tion
len(*g*)ths
intermitti(*e*)render
co(*n*)genital
thre(*s*)holds
de l'(*e*)space
si(*m*)ilar

stre(*n*)gthen
jud(*g*)mental
W(*a*)hrnehmungswelt
Romant(*i*)ker; Yuj(*e*)ro
on(*l*)y; persever(*a*)ting
Gestal(*t*)en; l(*i*)kely
caut(*i*)ous; differ(*e*)ntiating
for(*e*)see
Charlott(*e*)sville; rhy(*th*)mische
Mü(*n*)chen
b(*a*)sis; b(*r*)ought
visu(*a*)lization
psychi(*c*)al; Scho(*e*)nheinz
neces(*s*)arily
skel(*e*)ton; c(*l*)ose; pren(*a*)tal
appetit(*i*)ve; pleas(*a*)ntness; des(*s*)ert
p(*i*)ece; definite(*l*)y; l(*i*)ght
p(*l*)easantness; p(*l*)ane

If we take the five hundred commonest words in English reading matter* (which compositors of five years' experience would have set from a thousand or so to fifty thousand or more times), we find the following:

Omissions at the beginning of a word (5):
(*h*)and, (*in*)to, (*s*)mall, (*t*)his, (*t*)his.
Omissions at the end of a word (34):
a(*s*), befor(*e*), bu(*t*), case(*s*), case(*s*), change(*s*), doe(*s*), give(*s*), ground(*s*), ground(*s*), ha(*s*), in(*to*), it(*s*), know(*n*), light(*s*), love(*s*), on(*e*), othe(*r*), other(*s*), other(*s*), reach(*es*), show(*s*), sound(*s*), th(*e*), th(*e*), the(*ir*), the(*n*), time(*s*), time(*s*), up(*on*), wa(*s*), wer(*e*), with(*out*), word(*s*).
Omissions in intermediate positions (18):
ag(*a*)inst, a(*n*)d, b(*l*)ack, b(*l*)ack, b(*r*)ought, c(*l*)ose, len(*g*)ths, l(*i*)ght, mon(*e*)y, on(*l*)y, p(*i*)ece, re(*a*)d, re(*a*)d, re(*a*)d, somet(*h*)ing, t(*h*)e, t(*h*)ought, up(*o*)n.

By chance in such words omissions in initial, final, and intermediate positions would be as 57, 57, and 163.

We have examined in a similar way all the errors made by four individuals while learning typewriting, from about

* Plus also the plurals of the nouns included therein.

the ninth to the fifteenth hour of practice. We compare errors by omission of intermediate letters with errors by omission of initial and final letters, and with errors by addition. We do not count the omission of a space between words as an omission, nor the addition of a space within a word as an addition.

The errors in very common words and less common words which these individuals had typed correctly fairly often before the point at which our counts begin are shown below, the additions being printed in italics and the omissions being printed in italics and also enclosed in parentheses.

Additions to very common words:

among*b*, and*d*, b*r*eing, boo*l*k, bot*t*h, ca*b*n, do*dd*ing, *g*get, g*r*ain, his*o*, in*n*, *t*lines, made*e*, *h*more, of*q*, pe*r*ople, sim*l*ple, six*e*, suc*g*h, The*e*, *t*the, their*m*, the*b*n, the*y*n, the*s*, *n*things, to*m*, to*m*, until*l*, we*w*, who*m*.

Additions to less common words:

*a*aim, atten*ta*tiveness, business*s*, classe*r*ooms, control*e*, discard*e*s, discomfort*s*, enjoy*ee*, equip*t*ment, expert*h*, happiness*c*, impro*e*ve, innum*b*erable, *p*merely, measuring*g*, modifying*b*, m*e*useums, natur*e*al, *p*prey, primari*al*ly, repeat*i*edly, st*i*ring, studied*q*, substitu*ta*tion, telling*b*, *t*tendency, us*u*efully.

There are thus 31 additions in the common words, 27 in the less common, 58 in all.

Omissions from very common words:

a(*n*), an(*d*), befor(*e*), fro(*m*), ma(*n*), ma(*n*)y, n(*o*)t, ot(*h*)er, ro(*o*)m, so(*o*)n, th(*a*)t (space was used instead of the a), ther(*e*), Ther(*e*), t(*h*)ese.

Omissions from less common words:

(*al*)ready, acqua(*i*)ntance, av(*i*)ation, (*d*)esiring, (*e*)ducated, ether(*e*)al, ether(*e*)al, fi(*d*)get, fut(*u*)re, h(*a*)bits, h(*u*)man, imag(*i*)nation, man'(*s*), pe(*r*)haps (space was used for the r), prepo(*t*)ently, promis(*e*), purs(*u*)it, rec(*k*)oned, shov(*ing*), s(*p*)oken, sti(*t*)ches, th(*r*)oughout, to(*t*)al, tu(*r*)moil.

There are thus 14 omissions from the common words, 24 from the less common, 38 in all.

Additions occur oftener than omissions, especially in frequently used words. The omissions from the frequently

used words occur as initial letter once, final letter seven times, and intermediate letter seven times. By chance, the proportions would be as 15, 15, and 30 in these particular words; and that would be near the truth for such very common words in general. The number of omissions from intermediate positions is thus a trifle below what chance would give.

In the less common words the corresponding numbers are 3, 3, and 18 with the chances as 24, 24, and 132, or 3, 3, and 16½. The number of omissions from intermediate positions is here somewhat above what chance would give. However, it is likely that the ether(*e*)al error, which occurred twice in the same subject's work, was really an habitual misspelling. Omitting it, we have 3, 3, and 16 with the chances as 23, 22, and 120, or 3, 3, and 16.4.

On the whole, the facts give no support to the doctrine that the frequent repetition of a series of events in the mind or body in and of itself produces a tendency toward the omission of the intermediate terms of the series.

Dr. H. L. Hollingworth ['30, p. 457 f.] has commented on the former set of experiments as follows:

"In a recent number of the JOURNAL Freiberg, Dallenbach, and Thorndike question the natural dropping out of intermediate steps in the learning of an action series and cite certain observations which seem to merit further comment. The observations are that a count of errors made by hand-compositors shows that they do not make more errors of omission in the intermediate letters than in the case of the other positions. They do find more omissions than additions of letters and they find omissions more common in the case of words relatively little employed. They conclude that 'the facts give no support to the doctrine that the frequent repetition of a series . . . produces a tendency toward the omission of the intermediate terms of the series.' In this connection several points seem worth noting.

"In the first place, learning to spell involves a deliberate training *against* such a tendency as there may be to drop out middle letters. Hand-compositors have been, through long training and rigorous selection chosen on the basis of this correction. They are selected on the basis of the degree to which this natural tend-

ency has been trained out of them, so far as spelling words is concerned. Hence the non-occurrence of such errors would have no bearing on the existence of such a law, even if the spelling situation were otherwise relevant. Surely the place to observe a tendency is not in a situation from which it has been deliberately excluded by special training and selection.

"In the second place, the tendency as it has been stated has been given as a law of *learning*. Even in learning to spell this tendency is clearly operative; both pupil and teacher must struggle against it. A study of the locus of errors in misspelled words of six and seven letters in the case of school children is already on record which shows the facts clearly enough. The greater number of errors occurred in the middle and post-middle parts of words, and 'The children tended to make their misspellings too short rather than too long.' Training consisted in part in compelling them to overcome this tendency, so that they might become adequate hand-compositors and serve as subjects for Freiberg, Dallenbach, and Thorndike.

"In the third place it is doubtful if the mere act of spelling a word is really relevant to the problem. The law of 'omission of intermediate terms' describes what happens when an irritant leads to a behavior series which eliminates that irritant, thus putting an end to that particular activity segment, through the effect of the terminal act. Questions of the validity of the law should therefore be raised in situations to which the law is supposed to apply. It is at least far-fetched to consider the first letter of a word to be the motive, the middle letters to be unsuccessful responses, and the last letter a terminal adjustment that removes or alleviates the first letter.

"So long as the public insists that hand-compositors include all the letters of the words they spell, typographic errors made by such professional spellers, however interesting and instructive in other respects, are about the poorest place to find exhibited the laws of learning. In such a situation the laws may occasionally be illustrated, but only against great odds. This is in fact what Freiberg, Dallenbach, and Thorndike found. For there were really somewhat more omissions than interpolations, and they were more frequent in rare words, in the case of which the tendency had not yet been sufficiently trained out.

"There is of course some interest in looking for a thing in places from which it has first been carefully removed. Any appearance of the thing under such circumstances will indicate how very persistent it is. Negative results will of course be

wholly meaningless, but any positive indication, however slight, will be good evidence that the thing was really a fact and had not been wholly removed. It is just such shreds of positive evidence that are shown by the actual results of this careful counting of the errors of hand-compositors.''

We of course admit that training in spelling and typesetting would act against any tendency to the omission of intermediate physiological states by repetition. Such training is one of the ''other forces,'' but it would act equally against any tendency to the omission of initial states or final states.

We of course agree that if the tendency to the omission of intermediate states by repetition existed, it would be counteracted by training in spelling and the like. But if the tendency is a general law of learning, our statement that ''if the compositor's control broke down at all, so that he made mistakes of any sort'' the tendency should show itself, holds good. The training does not distinguish between errors initial, intermediate, and final.

The fact that, in general, errors in spelling occur more often in intermediate letters, and that the middle parts of words offer more difficulty than the ends, is probably not useful evidence concerning the existence of a tendency for a repeated series to drop its intermediate terms. The greater difficulty and more frequent mistakes in mid-parts of words are probably due to the greater frequency there of doubled letters, vowels, and vowel pairs.

Hollingworth's restriction of the law of ''omission of intermediate terms'' to the case where ''an irritant leads to a behavior series which eliminates that irritant, thus putting an end to that particular activity segment, through the effect of the terminal act'' is prudent; but Jennings made no such restriction and we are concerned with the general problem. Everybody admits that in many acts of learning there is much telescoping as learning progresses. The question is whether the repetition of the sequence, in and of itself, causes the omission of the intermediate terms,

or whether some force other than repetition, such as the consequences of the behavior, is necessary.

What is wanted as a test of the alleged general law of resolution of physiological states is a case where there is much repetition, and no more reward for omission of a mid-part than of an end-part. There may be any amount of punishment for omissions so long as the punishment is equal for all omissions and additions and so long as, in spite of the punishment, there are omissions or additions. Typesetting is a good test. The behavior series corresponding to common words has been repeated often and all errors have been punished almost alike. There is a slight favoritism to omissions rather than additions, since it is a trifle pleasanter to omit a letter and do less work, than to add one and do more. Omissions are thus on the average punished a little less than additions.

In the narrower field to which Hollingworth would restrict the law of resolution, it is not, in our opinion, the repetitions of the connections, but their consequences, which cause omissions. The experiments of other chapters and the general facts of life seem to us to prove this. By repetition alone, in such cases and all others, $A \longrightarrow B \longrightarrow C$ will never change save to a greater strength (as against $A \longrightarrow P$, $A \longrightarrow Q$, $A \longrightarrow R$, $A \longrightarrow S$, etc.). Only if $A \longrightarrow C$ occurs and results in more satisfaction than $A \longrightarrow B \longrightarrow C$, will B drop out.

CHAPTER IX

The Influence of the After-Effects of a Connection

§ 1. The inadequacy of frequency as a cause of learning

We have shown that the repeated occurrence of a situation, in and of itself, does not produce adaptive learning. But ordinarily, with the repeated occurrence of a situation, adaptive learning is produced. And it is, at least very often, produced in accordance with the immediate after-effects of the various connections with the situation in question. By and large, those connections which produce satisfying after-effects wax and those which produce discomfort wane.

We have shown that the repeated occurrence of a connection, in and of itself, does produce learning in the form of increased strength of that connection, but that this strengthening is rather slow. It is so slow that good teachers usually seek to supplement repetition by interest and reward. They not only arrange things so that the dog will stand up when they say "Beg, Rover" they also pat or feed him when he does so. They not only entice the child to say *cat* when he sees *c a t*, but praise him when he does so.

Much of learning seems to involve something more than the mere repetition of relevant sequences. Obvious cases are those where the response which was repeatedly made to a situation in its early occurrences is, in the end, displaced by a response which was very infrequent at the start.

Consider the following experiment: An individual supplies letters to complete a list of 160 words like those shown below. He is to write one letter for each dot.

bet...	aw.y
b..e	me..

c..ss	m.st
d..n	min.s
fa...	v...
f..e	p.nt
dig....	re..
fl..t	r..d
ju..	s.op
h..r	wi.e

He does this daily or oftener until he has written the series from 16 to 24 times including 16 to 24 completions of b.at. The records of eight individuals for the first sixteen series are shown in Table 76.

TABLE 76

LETTERS WRITTEN IN 16 SUCCESSIVE TRIALS TO COMPLETE *B.AT*

Subjects				
1	o o o o	o e o o	o o o o	o e e l
2	l e l e	l l l l	l l l l	l l l l
3	r o o o	o o l o	e o e o	o e o e
4	o o n o	o e o o	r r l l	l l l l
5	o o o o	r r o r	o l l r	o o o r
6	o o o o	o o l –	l r – o	l l l l
7	r r e o	r r r r	o r o r	o r r r
8	e r e e	e l l l	l l l l	l l l l

The situation, *Write a letter to make b.at into a word,* evoked the response of writing *o* in nine out of the first sixteen occurrences (two for each of eight subjects), but by the last sixteen *o* was the response only two times, whereas *l* was the response nine times. As you have doubtless guessed, the consequences attached to writing *o* and *l* were different. By the rules of this particular learning experiment, no letter save *l* was right as a sequent to *b* in *b.at.* When he had written *l* the subject was "rewarded" by the announcement of *Right* by the experimenter. When he wrote *o* he was "punished" by the announcement of *Wrong.* This is a sample of the many cases which may be observed in the laboratory or in life where frequency competes against the consequences of a connecting and loses.

Equally important and demonstrative are cases where,

at the first occurrence of a situation, each of say five responses has an equal probability (of approximately one in five or .20) of being made, whereas in the end four of them have a probability of zero and one a probability of 1.00, that one being the one whose consequence has been a satisfying *Right* compared with the annoying *Wrong* of the others. Any multiple-choice learning which begins with ignorance will serve. For example, subjects learned more or less of a vocabulary of 200 Spanish words arranged as shown below by choosing a meaning and being told *Right* or *Wrong*.

1. abedul	ameer birch couch carry punch
2. abrasar	oaf walk fill alienate burn
3. aceite	oil copper acerbity crab ferment
4. acometer	calculate asteroid escort attack credit
5. adefesio	defenceless relief nonsense support obstruct
6. adufe	execution burning speechless gold-mine tambourine
7. adunar	understand believe pray assist unite
8. aguante	watery chill want firmness serpent
9. alambre	retort candle copper feldspar verse
10. álamo	prison poplar siege sheep tocsin

Records of five subjects in response to line 1 follow:

Records of Five Subjects in Twelve Trials of Line 1 of C I (*abedul*, etc.) Made at Intervals of from ½ Hour to 24 Hours.

	1	2	3	4	5	6	7	8	9	10	11	12
N	5	3	5	3	5	4	1	2	2	2	2	2
P	3	5	4	4	2	2	2	2	2	2	2	2
Ra	4	2	2	3	2	2	2	2	2	2	2	2
Ro	4	1	1	2	2	2	2	2	2	2	2	2
St	3	3	2	1	5	1	5	2	1	2	3	2

Such cases of great strengthening of one connection compared with others of equal or nearly equal initial strength by reason of the different consequences attached to it and to them can be found by the thousands.

How the after-effect of a connecting strengthens or weakens the corresponding connection may well be a matter for dispute, but that it often does so seems to me as sure as the fact of learning itself.

Yet it has been an unpopular doctrine, and various attempts have been made to get along without it. The most promising of these argued that since the connection which led to the "successful" or *Right* consequence ended the series of varied responses to the situation, it must always occur at least once per occurrence of the situation, and so would, in the long run, have frequency in its favor, as compared with any one of the *Wrong* connections. This argument was unsound as to the facts, because very often a connection which is initially very strong and occurs often is replaced by one initially weak but having favorable consequences.

Kittens put in a box with bars in the front one and one-half to two inches apart, the door of which falls open when a loop of wire is pulled, will in the first experience try to squeeze through the opening in the front much more frequently than they will pull at the loop. Yet, at the end of forty or fifty experiences, they will almost always pull at the loop of wire, rarely or never attempting to squeeze through the openings. There are many, many similar cases.

Experiments like the one reported with completing words or selecting the right meaning, where each occurrence of the situation produces only one response, the situation being then rewarded, show the error of the assumption that the right response would be more frequent than any other one response. They can readily be arranged so that some wrong response is at the outset far more frequent. For example, subjects were required to estimate in square inches the areas of 74 shapes cut out of paper, with the aid of squares of 10, 25, and 50 square inches always present before them, and with announcement of *Right* and *Wrong* after a shape had been judged and removed from sight. Tables 77 and 78 show the records in cases where some one wrong response occurred much more often than the right response, yet was eventually displaced by the latter.

In Hamilton's experiment with six rats learning to escape by one out of four alleys, there were, in the first two

TABLE 77

RECORDS OF THE SUCCESSIVE ESTIMATES OF THE AREAS OF CERTAIN SHAPES

The record gives each estimate as a deviation (in square inches) from the correct area. 0 is thus a correct response.

Subject	Shape	Successive Estimates																											
M	1	−5	−7	−3	−9	−3	−5	−5	+1	−13	−5	−4	−2	−1	0	0	−7	0	0	0	−7	−7	0	0	0	0	0	0	0
	3	−8	−4	+2	−4	−4	−8	−4	−8	−6	−6	−4	−4	+2	+6	−4	−3	−4	−4	+2	0	0	0	0	0	0	0	+4	0
	4	−4	−8	−6	−7	−15	−11	+1	−4	−4	−4	−8	−7	−2	−5	−5	−1	−2	−2	−1	0	0	0	0	0	0	0	0	0
	9	−5	−5	−7	−5	−3	−9	−9	−7	−3	−3	−7	+5	−7	−1	−5	−5	−1	+3	−1	0	−7	0	0	0	0	0	0	0
	10	−4	−6	−4	−7	−5	−6	−3	−6	0	−1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Shape 1 thus had four −5's before any 0 but 0 prevailed
" 3 " " four −4's " " " "
" 4 " " four −4's " " " "
" 9 " " five −5's " " " "
" 10 " " three −6's " " " "

trials, three rats by whom some wrong alley was chosen two or two and one-half times as often as the right one. Two rats chose two or more wrong alleys each as often as the right. Only one rat chose the right oftener than any one wrong alley. Yet all soon came to choose the right alley invariably. (If we use the first trial alone, three rats chose some one wrong alley two or four times as often as the right, one chose the wrong alley as often as the right and two chose the right alone.)

Yerkes' monkeys Skirrl and Solke in all the harder problems (2, 3, and 4) of his multiple-choice experiment made some one wrong response much oftener than the right response in the first trials, yet they eventually discarded it entirely. The facts are shown in Table 78.

TABLE 78

FREQUENCIES OF THE RIGHT AND THE MOST FREQUENT WRONG RESPONSE BY THE MONKEYS SKIRRL AND SOLKE IN THE FIRST SERIES WITH THE YERKES MULTIPLE-CHOICE APPARATUS

		Settings										
		1	2	3	4	5	6	7	8	9	10	Total
Skirrl, Problem 2	Right	1	1	1	1	1	1	1	1	1	1	10
	Wrong	3	5	5	4	2	1	0	1	2	2	25
Solke, Problem 2	Right	1	1	1	1	1	1	1	1	1	1	10
	Wrong	8	4	5	5	1	5	1	1	3	6	39
Solke, Problem 3	Right	1	1	1	1	1	1	1	1	1	1	10
	Wrong	4	1	4	3	5	0	0	1	3	1	22
Solke, Problem 4	Right	1	1	*	1	*	*	1	*	*	1	5
	Wrong	2	6	*	6	*	*	2	*	*	5	21

* Mastery of these settings was not attained.

Gengerelli, who has made specific studies of learning where arrangements were made to give opportunity for frequency to compete with satisfyingness and to keep exact score of the results, reports results similar to those presented here ['29].

Facts such as these show the futility of the doctrine that the successful connection, by being the last to act on each

appearance of the situation, is more frequent than any other one and is strengthened by its greater frequency.

§ 2. Experiments on the influence of the after-effects of a connection

We may best consider first the most prominent theory of a positive influence of the after-effects of connections. This is the so-called Law of Effect that: "When a modifiable connection between a situation and a response is made and is accompanied or followed by a satisfying state of affairs, that connection's strength is increased: When made and accompanied or followed by an annoying state of affairs, its strength is decreased. The strengthening effect of satisfyingness (or the weakening effect of annoyingness) upon a bond varies with the closeness of the connection between it and the bond. This closeness or intimacy of association of the satisfying (or annoying) state of affairs with the bond in question may be the result of nearness in time or of attentiveness to the situation, response and satisfying event in question. 'Strength' means the same here as in the cause of the Law of Use." [Thorndike, '13b, p. 4.]

"By a satisfying state of affairs is meant roughly one which the animal does nothing to avoid, often doing such things as attain and preserve it. By an annoying state of affairs is meant roughly one which the animal avoids or changes."* [Thorndike, '13a, p. 123.]

I do not now accept the Law of Effect in this precise form. Its suggestion that the action of annoyers is the opposite of that of satisfiers in all respects is misleading. As we shall show in a later chapter, there are very important differences. Also, the closeness or intimacy of association is conditioned by the facts of belonging in general, as well as by attentiveness to the situation, response, and satisfier.

* I venture to emphasize two facts: (1) that satisfyingness and annoyingness are not synonyms for sensory pleasure and pain, and (2) that the act which is the second term of the connection need not be satisfying or annoying because its after-effects are.

Since, however, the Law of Effect is the accepted term for a general affirmation that satisfying and annoying after-effects of connections influence them, it seems permissible and convenient to so use it. Everything in this chapter, however, will be restricted to its statements concerning the effect of satisfiers.

As regards satisfiers, the two essential features of the quotations are the assertion that certain events which occur after a connection has operated can work back upon it to strengthen it, and the assertion that satisfying events are the kind which have this power.*

Consider the following experiment.

Experiment 43

A series of 50 strips of paper, containing two each 3, 4, 5, 6, . . . 27 cm. long, and alike in every respect except length, was presented on a fixed background in a random order. The subject, who had before him a strip 10 cm. long and known by him to be 10 cm., estimated the length of each strip in integral numbers. The 10 standard was kept fixed in a spot to the right of the lengths to be judged. The subject knew nothing concerning the constitution of the series of strips, save that they were all integral multiples of one-tenth of the standard. He never saw the strips save one at a time during the experiment.

After 50 judgments had been made with no aid save that which the subject could derive from the standard, and with no statement to him of any sort about the results, the series was presented in the following manner. A strip was placed before the subject. As soon as the subject announced his estimate, the strip was withdrawn, placed behind a screen and turned over, and the experimenter said *Right* or *Wrong*

* The quotations may also not unfairly be interpreted to mean that all satisfiers have this power, that each of them has it in all circumstances, and that they exercise it directly upon the connections which the satisfiers follow and to which they "belong." These qualities of universality, inevitableness, and direct influence will receive consideration later.

according as the estimate was right or wrong. No statement was made of the amount or direction of the error. The experimenter then recorded the estimate, and presented another strip. The statement of *Right* or *Wrong* came approximately 2 seconds after the subject's announcement of his estimate, and approximately 1¼ seconds after the strip was removed from his sight. After a number of such presentations of the 50 strips (usually seven, two or three a day for three or four days), the series was presented with no aid, save the presence of the standard 10, as in the first trial.

The results of these experiments are like those in which animals are rewarded by food or freedom or the like, after certain connections act; and are punished, or at least not rewarded, after certain other connections act. The satisfying connections are strengthened and the curve of successes rises indubitably and rapidly. The results are in striking contrast to those of experiments of similar nature in which no *Right* and *Wrong* consequences are attached to the connections.

Table 79 shows the essential facts for five subjects in the cases of whom the connections occasioned the effects of *Right* and *Wrong*. All subjects improved greatly. The average percent of reduction in the error was 61 with a probable error of ± 4.

The gain came partly by a reduction in constant errors for subjects Le, Li, and S, and partly by a reduction in the variable error for all. In the test before training, Le had a total of 52 units too low and 16 too high; Li judged the lengths 15 or less too low in 19 cases out of 26, and judged the lengths 16 or more too high in 19 cases out of 24; S had a total of 111 units too low and 1 too high. In the final test, Le's constant error was such as to produce 23 minus and 12 plus errors; Li's had been reduced to a slight tendency to estimate all lengths too low; S's had changed to a slight error in the opposite direction.

The reduction in the variable error may be measured by

the differences between the two early estimates and the differences between the two later estimates for the same lengths. The sums of these differences were:

	Before Training	After Training
A	19	8
Le	36	21
Li	37	10
S	30	12
Wi	25	12

With Table 79 we may contrast Table 80, which presents similar measurements in the case of subjects of similar general intelligence and initial ability in estimating the lengths in the cases of whom the same number of experiences occurred, but with no effects in the shape of announcements of *Right* and *Wrong*.

As a general check on the universality of the facts, and as a special check on the remote possibility that some personal influence of the experimenter might have in some way distorted the facts, Dr. H. H. Abelson did me the favor of repeating the experiment with six subjects, but with five instead of seven presentations with *Right* and *Wrong* as effects. The control subjects similarly had five presenta-

TABLE 79

THE INFLUENCE OF EFFECT: THE ACCURACY OF ESTIMATES OF LENGTHS 3 CM. TO 27 CM., A 10 CM. LINE BEING SHOWN

Sums of deviations from the true lengths; training with *Right* and *Wrong*

S	Test before Training	Training Periods 1	2	3	4	5	6	7	8	Test after Training	Percent of Reduction
A	33	47	32	31	27	22	22	13	14*	12	64
Le	68	59	46	49	43	37	26	26	41	35	49
Li	70	47	19	29	25	27	25	25		20	71
S	112	117	106	96	61	49	30	34		26	77
Wi	36	28	38	24	25	13	29	16		20	44
Sum	319	298	241	229	181	148	132	114		113	

Average 61 ± 4
Median 64

* Estimate from 25 judgments.

TABLE 80

THE INFLUENCE OF MERE REPETITION: THE ACCURACY OF ESTIMATES OF LENGTHS 3 CM. TO 27 CM., A 10 CM. LINE BEING SHOWN

Sums of deviations from the true lengths; training with mere repetition

S	Test before Training	Training Periods 1	2	3	4	5	6	7	Test after Training	Percent of Reduction
T	34	21	27	24	24	18	37	20	36	−6
K	61	73	41	50	55	48	60	58	40	34
R	50	38	52	42	38	40	37	33	49	2
H	54	38	48	34	33	25	52	35	35	35
M	99	126	125	128	126	89	79	93	89	10
C	91	70	84	107	66	85	77	93	116	−27
F	43	55	70	53	54	55	78	72	86	−100
Sum	432	421	447	438	396	360	420	404	451	

Average −7 ± 12
Median 2

tions with no aid. The results, shown in Table 81, are closely similar to those of the first experiment. The average percent of reduction in error is 50, with a probable

TABLE 81

THE INFLUENCE OF EFFECT: THE ACCURACY OF ESTIMATES OF LENGTHS 3 CM. TO 27 CM., A 10 CM. LINE BEING SHOWN

Data by Abelson

Sums of deviations from the true lengths before and after 5 periods of training with *Right* and *Wrong*

S	Before	After	Percent of Reduction
A	53	37	32
B	72	13	82
C	57	40	30
D	34	14	59
E	106	67	37
F	128	49	62
Sum	450	220	

Average 50 ± 5
Median 48

Sums of deviations from the true lengths before and after 5 periods of training by mere repetition

S	Before	After	Percent of Reduction
G	70	61	13
H	56	104	−86
I	60	54	10
J	66	46	30
K	82	59	28
L	136	80	41
	470	404	

Average 6 ± 12
Median 21

error of ± 5. The average percent of reduction for the control group is 6, with a probable error of ± 12.

These experiments are crucial as a demonstration that the consequences of a connection work back upon it to influence it. There is no difference between the *Aided* and *No Aid* experiences save in the consequences of the connections. They also provide evidence that the consequences probably act on the connection directly, and not by leading the subject to repeat it, or something like it, to himself. Strictly speaking, he could not repeat *it*, but at most could hold in mind some sort of image or illusion of the strip and repeat the approved estimate as a response to this image or illusion. He had little time to do this because a new length was presented about a second after the *Right* or *Wrong* announcement was made. It is highly improbable that such images would be sufficiently accurate to serve as substitutes for the real strips.

§ 3. The law of effect and other explanations of learning

The Law of Effect seems to explain such learning as this and such as has been displayed by hundreds of animals who have learned to manipulate mechanisms, respond to signals, and choose between doors or paths rather well. The objections to it are due partly to certain alleged inadequacies in it, and partly to a reluctance to believe that what happens after a connection can influence it. Objections have been felt emphatically and have led to alternative theories of learning by the potency of some feature of the response which is the second term of the connection, such as its frequency, recency, intensity, congruity with the animal's purpose or set, completeness, finality or consummatory quality, freedom from inhibition, or more facile association with the dominant tendency.*

* A critical review of the objections made to the Law of Effect and of the alternative theories proposed by Hobhouse, Holmes, Woodworth, Carr, Peterson, Cason, Hollingworth, Tolman, McDougall, Koffka, and others will be the

To decide between the Law of Effect and these proposed substitutes, we need experiments in which two or more connections are equal in respect to frequency, recency, intensity, completeness, finality, congruity, etc., one having a satisfying after-effect and the others none. We have spent much time in devising and carrying out experiments so varied in the content of the learning as to preclude any narrow or unfair sampling and to provide a crucial test.

Before proceeding to report them, we may profitably note also doctrines which, openly or tacitly, admit that satisfying states of affairs attached to a connection strengthen it, but deny that they do so by any sheer and direct potency, asserting on the contrary that they do so by leading the individual to retain, repeat, rehearse, or emphasize the connection or some ideational parallel and equivalent of it. For example, S leads to R_1, R_2, R_3, and R_4, of which R_4 has attached to it A_4, a satisfying state of affairs. When $S \longrightarrow R_4\ A_4$ occurs, the individual then and there repeats R_4 or some inner symbol of it. This certainly often happens in learning, as when a person on learning German equivalents of English words says over to himself the meaning which he finds is the right one. In learning acts of skill, there is a tendency to try to hold in mind the "feel" of an act which is rewarded.

When S recurs, the individual may recall the past effects of $S \longrightarrow R_1$, $S \longrightarrow R_2$, $S \longrightarrow R_3$, and $S \longrightarrow R_4$ and emphasize the last because of the memory of A_4.

We need experiments which will differentiate a general, inevitable, direct influence of a resultant satisfier from its influence by stimulating the individual to a deliberate retention or repetition of some ideational equivalent of the connection.

Besides this ideational influence of the satisfying after-effect at the time of the connection, there may be a re-

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subject of a later chapter, after the new experimental results have been presented.

hearsal with selective emphasis at the time of the next occurrence of the situation.

This sort of influence has been urged as a substitute for the direct action of satisfiers by Hollingworth, who writes:

"Even the lower animals are trained by punishing or rewarding them for their bad and good acts, respectively. Can this practice, with its undoubted practical warrants, be justified and explained without assuming that pleasantness and unpleasantness, or their physiological correlates, work *backward* by way of 'stamping in' or 'stamping out' the movements which produced them or were followed by them? . . .

"There is a very ready answer, and it is astonishing how commonly it is overlooked. Pleasantness and unpleasantness, reward and punishment, do affect conduct. They do so, however, by modifying the *stimulus*, not by mystical operations on the movements. The burnt child shuns the fire, not because pain did anything to his movements, but because, since that pain, the stimulus has changed. It is no longer 'flame plus curiosity'; it is now 'flame plus fear.'

"For the present stimulus is not merely the flame, which may be, for the fireman, an abstract and isolated object. The present stimulus is the total situation of the moment, the complete antecedent of present behavior. This includes the seen flame, plus the imaged pain, plus the fearful emotion redintegrated by the flame on the basis of previous context. The 'avoiding reactions' are not merely to the flame but to this total situation. Once the stimulus was visual pattern, plus interest; now it is visual pattern, plus imaged pain pattern, plus emotional tone of strong fear." ['28, p. 218f.]

It will be desirable to include among our experiments some which avoid all possibility of such inner revival of ideas of after-effects.

Köhler and other Gestaltists choose not to consider learning in terms of the strengthening of connections, and do not specifically consider the question of the influence of after-

effects upon connections. But presumably Köhler's doctrine of equilibrium applied to our case would mean either that, in learning, those after-effects which bring or restore an animal to a state of inner equilibrium or peace do strengthen the connections which produce them, or that connections themselves in general tend to become strong in proportion as they produce such inner equilibrium. However this may be, we have planned experiments in which closure and equilibrium are equal for the rewarded and the unrewarded connection (except, of course, in so far as equilibrium means simply a satisfying state of affairs, "one which the animal does nothing to avoid, often doing such things as attain and preserve it").

Not all of our experiments equalize everything except satisfying after-effects perfectly and exclude absolutely every possibility of selective emphasis by retention or revival of the connection or some ideational representative of it, but some of them approximate this ideal very closely and all of them will, I hope, be found instructive.

§ 4. Further experiments

We report five experiments in which the strengthened connection is not favored by frequency, recency, intensity, freedom from inhibition, etc., and in which the opportunity for emphasis by inner retention or revival is minimized by having the response be one that is very hard to retain or revive, or by leaving very little time between the recurrences of the situation, or both.

*Experiment 44**

In Experiment 44, the connections were between the commands, *Draw a 3-inch line, Draw a 4-inch line, Draw a 5-inch*

* The writer is responsible for the general plan of Experiment 44 and for the treatment of the results, but the credit for the details of its execution belongs to Dr. Elsie O. Bregman. With the assistance of members of the staff of the Institute of Educational Research, she conducted all the tests and training and supervised the scoring and tabulating of results.

line, Draw a 6-inch line, and the response of drawing under conditions described below. The effects were *Right,* said by the experimenter when the line drawn was within 1/8 inch of the correct length in the case of 3-inch lines, or 1/4 inch of the correct length in the case of the other three lengths, and *Wrong* said in other cases.

The procedure in learning to draw lines of stated lengths with eyes closed was as follows:

The subject was seated, blindfolded, at a table opposite the experimenter, and in front of a drawing board, along the left hand edge of which a strip of veneer about 2 inches wide had been fastened in such a way that a large sheet of cross-section paper (16 x 21 inches) could be slipped between it and the board and fastened to the board by means of two or three carpet tacks. The strip of veneer served as a fixed starting edge for all lines. The cross-section paper itself was so ruled, in pencil, as to make it possible for the experimenter to tell readily the length of any line drawn from the strip as zero.

The subject was instructed to draw lines of a given length, starting always from the strip of veneer at the left, and to wait after each line until hearing the score called, before drawing the next line. He was required to draw each line with one continuous, quick movement.

The subjects were trained to draw 3, 4, 5, and 6 inch lines at a single sitting. The subject was instructed to draw lines of a given length, waiting after each line to hear its score, until directed to draw lines of a different length. The number of successive repetitions of a single length varied between 4 and 8, and the lengths followed each other, not numerically, but in a random order, according to a prearranged scheme. This scheme, which we shall call the 600 series, since it is made up of a series of 600 lines, 150 of each of the four lengths, was followed at each test period and training period.

Twenty-four subjects were tested with this series with no announcement of *Right* or *Wrong,* before and after seven

training periods, at least a day apart, in which *Right* or *Wrong* was announced about one second after each response. From start to finish, no subject ever saw any line that he drew, or had any practice other than that described above.

The percent of right responses in each training period and the percent which would have been right (if announcement had been made) in the early and late tests are reported for each subject in Table 82. Every subject im-

TABLE 82

THE INFLUENCE OF EFFECT UPON DRAWING LINES WHEN BLINDFOLDED: THE PERCENT OF RIGHT RESPONSES IN EARLY AND LATE TESTS AND DURING THE TRAINING ITSELF

Subject*	Early Test	Percent Right Training Periods 1	2	3	4	5	6	7	Late Test	Gain: Late over Early
16	1	38	48	49	52	56	54	61	21	20
17	28	47	56	69	61	65	68	67	21	−7
18	2	40	47	50	51	58	55	57	33	31
19	13	34	33	47	53	49	35	56	39	26
20	0	25	42	45	40	47	41	44	30	30
21	15	30	47	52	58	58	58	57	37	22
23	13	35	43	42	47	48	52	60	9	−4
25	1	37	38	44	44	44	55	60	28	27
26	16	46	50	43	49	34	51	54	28	12
27	12	37	43	45	35	45	49	60	36	24
28	12	33	38	39	50	30	46	42	11	−1
29	24	55	62	75	77	85	88	93	65	41
33	0	32	48	50	24	36	44	47	35	35
34	16	31	34	36	48	48	55	55	31	15
35	11	26	33	32	46	38	46	33	6	−5
36	0	0	18	41	43	50	46	47	20	20
37	6	41	53	51	54	61	53	65	24	18
40	24	33	34	37	32	37	41	46	28	4
41	28	39	40	40	36	46	40	41	25	−3
42	31	34	38	41	40	30	48	50	4	−27
43	7	31	34	27	35	41	40	39	21	14
44	24	36	44	51	49	53	60	62	35	11
46	20	36	42	45	52	48	48	53	11	−9
48	13	26	38	50	53	46	54	48	9	−4

* It may be of interest to know that subjects 16 to 29 were from 20 to 25 years old, and subjects 33 to 48 were 35 years old or over, averaging 42 years.

proved during the training, though the gain of subject 41 was so small as to be uncertain.

The percent right rose from a median of 13 in the early test to a median of 34½ in the first training period, and a median of 54½ in the seventh. In the late test, when the subjects were without any guidance and connection from the announcements of *Right* and *Wrong* the percent fell back to a median of 26½, but was twice as large as in the early test. Sixteen of the twenty-four subjects had more right in the late than the early test. The average gain was 12, with a probable error of 2.2.

A more accurate estimate of the influence of the right and wrong conceptions of the connections may be had by measuring each line drawn and computing the average errors in the early and late test for the four lengths. This we have done with the results shown in Table 83. There is a reduction in the error for each length and for eighteen of

TABLE 83

THE INFLUENCE OF EFFECT UPON DRAWING LINES WHEN BLINDFOLDED

	Average Divergences								Changes				
	3"		4"		5"		6"						
S	Before	After	Before	After	Before	After	Before	After	3"	4"	5"	6"	Total
16	98	41	143	47	201	53	232	114	− 57	− 96	−148	−118	−419
17	28	32	44	59	69	61	84	81	+ 4	+ 15	− 8	− 3	+ 8
18	87	27	125	36	130	49	141	47	− 60	− 89	− 81	− 94	−324
19	59	33	96	29	113	37	131	38	− 26	− 67	− 76	− 93	−262
20	129	38	190	38	222	57	250	52	− 91	−152	−165	−198	−606
21	38	42	66	29	78	29	93	34	+ 4	− 37	− 49	− 59	−141
23	64	44	76	65	73	113	99	163	− 20	− 11	+ 40	+ 64	+ 73
25	111	22	150	33	208	64	262	64	− 89	−117	−144	−198	−548
26	80	36	68	35	93	54	84	47	− 44	− 33	− 39	− 37	−153
27	54	35	91	30	97	39	111	46	− 19	− 61	− 58	− 65	−203
28	79	58	79	103	103	89	115	94	− 21	+ 24	− 14	− 21	− 32
29	62	18	71	22	65	25	66	22	− 44	− 49	− 40	− 44	−181
33	212	27	210	23	275	34	336	40	−185	−187	−241	−296	−909
34	84	27	87	34	90	57	101	81	− 57	− 53	− 33	− 20	−163
35	63	56	103	80	126	97	146	116	− 7	− 23	− 29	− 30	− 89
36	94	45	151	65	202	53	279	62	− 49	− 86	−149	−217	−501
37	36	43	83	42	150	69	179	54	+ 7	− 41	− 81	−125	−240
40	50	32	57	48	64	62	76	58	− 18	− 9	− 2	− 18	− 47
41	37	54	45	48	56	51	71	78	+ 17	+ 3	− 5	+ 7	+ 22
42	58	76	56	122	71	165	70	189	+ 18	+ 66	+ 94	+119	+297
43	104	48	112	78	115	54	110	72	− 56	− 34	− 61	− 38	−189
44	76	24	58	45	56	37	55	45	− 52	− 13	− 19	− 10	− 94
46	33	46	45	93	73	93	86	143	+ 13	+ 48	+ 20	+ 57	+138
48	75	80	79	70	101	98	91	106	+ 5	− 9	− 3	+ 15	+ 8
Av.									− 35	− 42	− 54	− 59	−190
P. E. of Av									± 5	± 7	± 9	± 11	± 25

the twenty-four subjects. The average reduction is nearly eight times its probable error. The improvement is due partly to the reduction of constant errors (the usual tendency was to draw too short lines) and partly to the reduction of variable errors.

It is reasonable to assume that mere repetition of such line-drawing with no difference in the effect of accurate and inaccurate responses would produce zero reduction in the error. It seems better, however, to check this assumption by experiment.

This we have done with twelve subjects, the results being shown in Table 84. Each of them drew 4200 lines in seven training periods preceded by a test of 600 lines and followed by a similar test. The average result of the unrewarded practice was approximately zero change, viz., an increase in error-sum of .06 inch. The probable error of this determination is .47 inch. The difference of 1.96 inches in favor of the reward practice has as its probable error $\sqrt{.25^2 + .47^2}$, or $\pm .53$.

TABLE 84

THE INFLUENCE OF REPETITION ALONE UPON DRAWING LINES WHEN BLINDFOLDED

	Average Divergences								Changes				
	3"		4"		5"		6"						
S	Before	After	Before	After	Before	After	Before	After	3"	4"	5"	6"	Total
C	89	45	97	46	109	46	101	62	−44	− 51	− 63	− 39	−197
M	58	38	55	54	53	72	57	113	−20	− 01	+ 19	+ 56	+ 54
P	87	38	143	42	172	62	353	61	−39	−101	−110	−292	−542
R	66	32	82	40	108	84	163	109	−34	− 42	− 24	− 54	−154
S	70	55	80	76	78	221	95	221	−15	− 04	+143	+126	+250
W	66	82	60	93	64	127	72	98	+16	+ 33	+ 63	+ 26	+138
L	50	103	81	163	103	206	133	261	+54	+ 82	+103	+128	+367
T	136	141	162	153	187	305	227	302	+05	− 09	+118	+ 75	+189
D	93	51	92	91	83	129	125	204	−42	− 01	+ 46	+ 79	+ 82
J	31	29	33	50	51	42	59	43	−02	+ 17	− 09	− 16	− 10
DB	97	121	104	127	144	179	202	267	+24	+ 23	+ 35	+ 65	+147
CC	111	69	150	134	186	100	243	126	−32	− 16	− 86	−117	−251
Av.													+ 06
P. E. of Av.													± 47

To make sure that these subjects were not, by nature, less capable of improvement in the ability than adults in gen-

eral, six of them (C, M, P, R, S, and W) who had thus practiced with no after-effects in the form of announcements of *Right* and *Wrong* were later given the training of drawing 3000 lines with such announcements (preceded and followed by a test as before). The results, shown in Table 85, were that all six improved. The average reduction in the sum of the four average errors was 1.41 with a P. E. of .25 inch.

TABLE 85

THE INFLUENCE OF EFFECT IN SIX SUBJECTS FROM THE GROUP WHICH MADE ZERO IMPROVEMENT BY REPETITION ALONE

	Average Divergences								Changes				
	3"		4"		5"		6"						
S	Before	After	Before	After	Before	After	Before	After	3"	4"	5"	6"	Total
C	45	30	46	40	46	40	62	43	−15	− 6	− 6	− 19	− 36
M	38	27	54	23	72	35	113	36	−11	−31	− 37	− 77	−156
P	38	20	42	23	62	33	61	45	−18	−19	− 29	− 16	− 82
R	32	33	40	30	84	40	109	46	+ 1	−10	− 44	− 63	−116
S	55	50	76	52	221	74	221	70	− 5	−24	−147	−151	−327
W	82	42	93	63	127	97	98	100	−40	−60	− 30	+ 2	−128
Av.													−141
P. E. of Av.													± 25

Three of these six subjects (M, R, and W) continued the practice with announcements of *Right* and *Wrong*, and made noteworthy further improvement. M reduced her sum of the average divergences from the correct length by .45, .22, .07, and .08 inch in four successive weeks of practice, 4200 lines being drawn each week, becoming able to draw with average errors of .08, .09, .11, and .11 inch for the four lengths. R reduced the sum of her average divergences from the correct lengths by 68, 0, 15, and 11 in the four successive weeks, becoming able to draw with average errors of .09, .14, .15, and .17 inch. W reduced the sum of her average divergences by 2.13 the first week, increased it by .29 the next, decreased it by .55 the third, and decreased it by .06 the fourth, being able at the end to draw lines with average errors of .11, .13, .18, and .15 inch. The reduction is partly by a reduction in the constant error and partly by a reduction in the variable error.

There is the possibility that the beneficial action of the

reward in these experiments consisted, in whole or in part, in the temporary retention in memory by the subjects of some methods or ideas or guiding sensations, and the deliberate effort to make such movements as were in harmony with these. The possibility is slight since the existence and helpfulness of such methods, ideas, or sensations are very problematic. But we can reduce it still further by performing the same experiment with series in which the situation changed with each movement, in which, that is, there were no sequences of 3″ or 4″ or 5″ or 6″. In these new series the retention in memory would have to persist past one or more appreciations of new situations and responses thereto.

Experiment 45

The subjects drew 20 lines with no announcement of *Right* or *Wrong*, then 100 lines with announcement of *Right* or *Wrong*, then 20 lines without announcement of *Right* or *Wrong*, then 100 lines with announcement of *Right* or *Wrong*, and so on. In all these, no commands were given for sequences of the same length. Each 20 without announcement of *Right* or *Wrong* will be called a *test*. Each 100 with announcement of *Right* and *Wrong* will be called a *practice*.

Table 86 shows the number of correct responses for each individual in each test. Ten of the twelve showed clear

TABLE 86

DRAWING 3″, 4″, 5″, AND 6″ LINES, WITH NO SEQUENCES: THE NUMBER OF CORRECT RESPONSES IN EACH TEST OF 20 TRIALS

	Bi	Ha	Wad	Mi	Ed	Da	Ke	Hal	Sa	Co	Ba	St	Average
Day 1, Test 1	0	0	0	5	0	0	0	0	7	1	0	1	1.17
" 2	4	2	8	13	3	0	0	8	4	3	0	6	4.25
" 3	5	7	2	19	0	0	5	8	15	2	0	9	6.00
" 4			2			9	0		0	4	5	1	
Day 2, Test 1	5	2	1	12	0	5	0	0	0	0	1	7	2.75
" 2	1	7	3	14	3	11	0	9	7	4	3	9	5.92
" 3	2	5	9	20	3	9	2	10	7	1	8	6	6.83
" 4		0	12	17		13	10	9	14	4	4	6	
Day 3, Test 1	4	0	2	12	4	4	1	6	0	3	9	2	3.92
" 2	5	7	7	14	6	7	9	10	5	6	11	8	7.92
" 3	11	6	6	14	1	9	9	7	2	5	9	8	7.25
" 4	6	1	3	11		2	11	5	7	6	11	6	

improvement.* The average number of correct responses out of 20 rose from 1.17 in the first test of the first day to 2.75 in the first test of the second day, and to 3.92 in the first test of the third day. During each day it rose still higher, the high point being 7.92 for the second test of the third day.

We have also computed and examined the median errors (i.e., deviations regardless of signs from the 3″ or 4″ or 5″ or 6″) for each individual for each test of days 1 and 3. As a convenient rough measure of improvement, we may take the reduction in the sum of these four median errors. Table 87 shows these sums for each individual for tests 1, 2, and 3 on days 1 and 3. There is clear evidence of improvement, as before, for all save Ed and Sa. With Ed it is questionable; Sa showed none.

TABLE 87

DRAWING 3″, 4″, 5″, AND 6″ LINES, WITH NO SEQUENCES: SUMS OF THE MEDIAN ERRORS (REGARDLESS OF SIGNS) FROM 3″, 4″, 5″, AND 6″. IN TENTHS OF AN INCH

	Bi	Ha	Wad	Mi	Ed	Da	Ke	Hal	Sa	Co	Ba	St	Sum
Day 1, Test 1	64	106	60	22	55	76	80	89	17	47	103	52	771
" 2	19	24	14	10	23	88	47	15	18	25	66	13	362
" 3	17	15	32	4	67	96	30	14	14	59	43	12	403
Day 3, Test 1	26	43	37	10	39	20	36	14	83	21	17	40	386
" 2	15	17	18	14	20	11	15	11	17	13	9	17	177
" 3	10	19	6	6	68	12	16	13	35	29	17	11	242

The improvement, as will be shown presently, consists chiefly in the elimination or reduction of a constant tendency, usually to draw too short lines. Sometimes the elimination of this is followed by a tendency to draw too long lines, which tendency may be eliminated in its turn. A reduction of the variable error around the average length that is being drawn at any time appears rarely, if at all, in these records; but if the experiment had been long continued, this would doubtless have occurred with some or all individuals as it did in the previous experiment with individuals 16 to 48 and C, M, P, R, S, and W.

* Ed showed probable improvement; Sa showed none.

The evidence that the improvement consists in the reduction of constant errors rather than variable errors, and especially in the reduction of a constant error toward drawing too short lines, is to be found by measuring the deviations of the lengths drawn from the correct length (3″ or 4″ or 5″ or 6″) and also from the average or median length of the lines being drawn at the time (say within the same test) by the individual in response to *Draw 3* or *Draw 4*, etc. In this treatment we may best omit Sa, who showed no evidence of improvement during the experiment, presumably because she had no constant error at the beginning (9 lines too long, 9 lines too short, and 2 lines recorded as 0 because less than ⅛ or ¼ inch from the correct length).

All the others but Mi had pronounced constant errors in the first test of day 1, the median deviations (regarding signs) from the correct length being minus for all four lengths and summing to from —47 to —106. Mi had 14 lines too short and 6 too long.

As a result of the practice these large negative constant errors were greatly reduced. Ed fell into even larger positive constant errors from time to time, but the other ten kept fairly free from constant errors after they had got rid of the one initially present.* These reductions account for most, if not all, of the improvement. The averages of the variable errors, measured from the median of the five lengths of a certain sort drawn in each test were computed, but are not reported in detail here. From test 1 of day 1 to test 1 of day 3, there are 25 decreases and 23 increases. From test 1 of day 1 to test 2 of day 3, there are 17 decreases, 2 zero changes, and 29 increases. From test 1 of day 1 to test 3 of day 3, there are 16 decreases, 2 zero changes and 30 increases. From test 1 of day 1 to tests 1, 2, and 3 of day 3, there are thus 58 decreases, 4 zero changes, and 82 increases. Similar figures for the change in the variable error from test 2 of day 1 to tests 1, 2, and 3 of

* Sa, who had none at the start, fell into a large positive constant error at the beginning of day 3.

day 3 are 60 decreases, 5 zero changes, and 79 increases. Similar figures for the change from test 3 of day 1 to tests 1, 2, and 3 of day 3 are 77 decreases, 7 zero changes, and 60 increases. From day 1 as a whole to day 3 as a whole there are 195 decreases, 16 zero changes, and 221 increases.

In Experiments 44 and 45, the connection (or response) followed by *Right* has no advantage over the connection (or response) followed by *Wrong* in frequency save what it acquires secondarily by the improvement due to the after-effects themselves. At the beginning, responses of 2¼ to 2¾ inches to *Draw 3 inches* are more frequent than responses of 2¾ to 3¼ inches. The same is true for the other lengths. There is at the beginning, in general, a tendency to draw lines too short.

It has no advantage in recency. The interval from a right connection to the next is, if anything, a little longer than the interval from a wrong connection to the next, since the experimenter requires on the average a longer time to make sure that the line is within the ¼ inch limits than to make sure that it is outside them.

It has no advantage in intensity, save such as the after-effects themselves may give. Nothing in the shove of the pencil is more intense when the line is right than when it is wrong.

It has no advantage in congruity or harmony with the subject's purpose or "set" or "adjustment" save what the after-effect gives. Since each subject tried consistently to do his best, all the shoves made are equally congruous with the subject's purpose until he finds out by their after-effects that some are satisfactory and some are not.

It has no advantage in completeness, finality, or consummatory quality, except such as the after-effect itself may give. Except for that, every shove completes or ends or consummates itself. In so far as further secondary consummation or completion is given by the *Right* or *Wrong*, this is no more complete or final for the *Right* than for the *Wrong*, except that the *Right* may leave the organ-

ism, or the recently active parts of the organism, more in peace, rest, freedom from tension, or the like, whereas the *Wrong* may leave it in a condition of irritation, "tension," unfulfilled craving, or the like. This may well be, and may be all or part of the mechanism by which the satisfying after-effect does strengthen the connection. Such a condition would be a consequence or correlate of the fact that hearing *Right* is, under the conditions of the experiment, a state of affairs which the subject "does nothing to avoid, often doing such things as attain and preserve it."

It has no advantage in freedom from inhibition except such as the after-effect itself causes. Neither shove is inhibited at all during its progress, nor displaced at its end. If the physiological process corresponding to the right connection is less inhibited after the event than is the process corresponding to the wrong connection, this is due to the *Right* and *Wrong*, and is precisely a relative strengthening of the one connection by its satisfying after-effect.

A connection (or response) followed by *Right* has no advantage over one followed by *Wrong* in any relation to the dominant activity. In fact, making the shoves at command seems to be itself the dominant activity in these experiments.

In general, up to the point when the subject hears *Right* or *Wrong*,* nothing in the external situation or the connection or the response favors one connection rather than another.

But conceivably the subject on hearing *Right* may try to repeat some inner equivalent of the connection which has just operated, as by thinking "Five inches, do like this, or shove so as to have this sensation." In sophisticated human learning of matters where the response is easily available or get-at-able, something like this is often done. To discourage the tendency to do this and to make it unprofitable,

* **Occasionally, by a slip, a subject makes a shove which he himself judges to be too short or too long. This *Wrong* which he thus announces to himself is of course an after-effect, just as truly as one that comes *ab extra*.**

the time between shoves was made as short as possible in both experiments and all sequences were avoided in Experiment 45. The learning in the latter did not suffer, so far as can be judged from the records.

Conceivably the subject may, as learning progresses, revive memories of how he behaved in making past shoves plus memories of their respective success or failure. In sophisticated human learning this, too, is often done. To the constant external situation may be added a change in him, due to the after-effects, but produced by the ordinary laws of association whereby he hears *Draw 4 inches*, plus some ideational revival. I do not think this occurs, save very rarely, in experiments of only 750 or 1050 shoves of each length. The right responses in this experiment do not easily become available for ideational representation; and guiding sensations have little chance to act in the course of so simple and rapid a movement. The guidance has to operate largely when the movement starts. In very long-continued practice with reward, cues of one sort or another may become available, though even in such cases it is doubtful whether they are causes or results of improvement. However, this whole question may be left for settlement by experiments which are crucial with respect to it.

As regards "closure," the right and the wrong connections are all closed. Each trial is a complete unit, beginning with *Draw—inches* and ending with the shove. Each trial plus the announcement of its result is a larger complete unit. A *Wrong* closes it as truly as a *Right*, the only difference being in the satisfyingness of the former.

As regards "equilibrium," there seems to be no advantage to the right connections save what the greater satisfyingness of the *Right* produces. In both cases the organism turns from the task done to set itself for the next to be done. After *Right* there may be also a state of relative composure, rest, acceptance, or the like; and after *Wrong* there may be a state of relative annoyance, unrest, irritation, inadequacy, or the like. The former may be, or be a

TABLE 88

NUMBER OF CORRECT JUDGMENTS OUT OF 146 IN SUCCESSIVE PAIRS OF TRAINING SERIES OF LINES 3″, 3¼″, 3½″, 3¾″ . . . TO 12″ IN LENGTH

Subject	Number Correct in Trials 1 and 2, 3 and 4, 5 and 6, etc.																				
M	1	9	17	15	27	26	13	31	32	32	35	39	38	33	35						
N	6	16	24	27	20	36	22	36	33	37	31	37	43	44	46	44	42	41	61	40	41
P	7	21	20	36	40	35	44	46	38	26	24	51	40	32	36	38	21	17	22		
R	31	27	23	21	30	30	37														
Ro	0	27	33	46	34	61	50	45	45	48											
Sp	26	20	28	24	41	27	21	31	22	23	25	34	31	32	31	35	30	33	26	29	
Average	12	20	24	28	32	36	31														

sign of, the physiological equilibrium which Köhler and others think the organism tends to seek. The satisfying after-effect may strengthen connections by producing such a state, which presumably would favor the retention more than the upsetting of connections associated with it. This would be entirely consistent with the Law of Effect.

Experiments 46a and 46b

Experiment 46a was like Experiment 43, except that the lengths ran 3″ to 12″ in multiples of ¼″. Six subjects were given practice with announcements of *Right* and *Wrong* just as in Experiment 43. The records appear in Table 88. Two subjects, R and Sp, who were at the beginning free from constant errors, improved very little. The others improved rapidly at first and then very slowly.

TABLE 89

NUMBER OF CORRECT RESPONSES (OUT OF 80) IN ESTIMATING LENGTHS 2½″, 3″, 3½″, 4″ . . . TO 12″, IN SUCCESSIVE TRIALS

Ch	26	24	31	27	23	44	33	38	38	31	15	30	28	45	33	39
Dr	8	22	21	20	32	31	26	29	30	31	35	54	42	43	33	52
L	30	30	41	42	49	55	55	55	59	60	57	64	51	60	58	56
O	42	44	44	47	50	59	51	47	44	42	51	46	47	47	48	46
Average	26½	30	34			42				43				45½		

Experiment 46b was like Experiment 43 and 46a, except that the lengths ran from 2½″ to 12″ in multiples of ½″. The facts appear in Table 89.

Experiment 47

This experiment, 47, adds nothing to the results of Experiments 43, 44, and 45 save (1) general confirmation and (2) extension to the strengthening of connections between a set of more variant situations and a set of very much more complicated acts, in a case in which (3) the satisfying state of affairs was delayed longer after the activity of the connection (3 to 6 seconds).

A heavy table with top set horizontally was made with a series of concentric rings of diameters 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 centimeters, as shown in Figure 5.

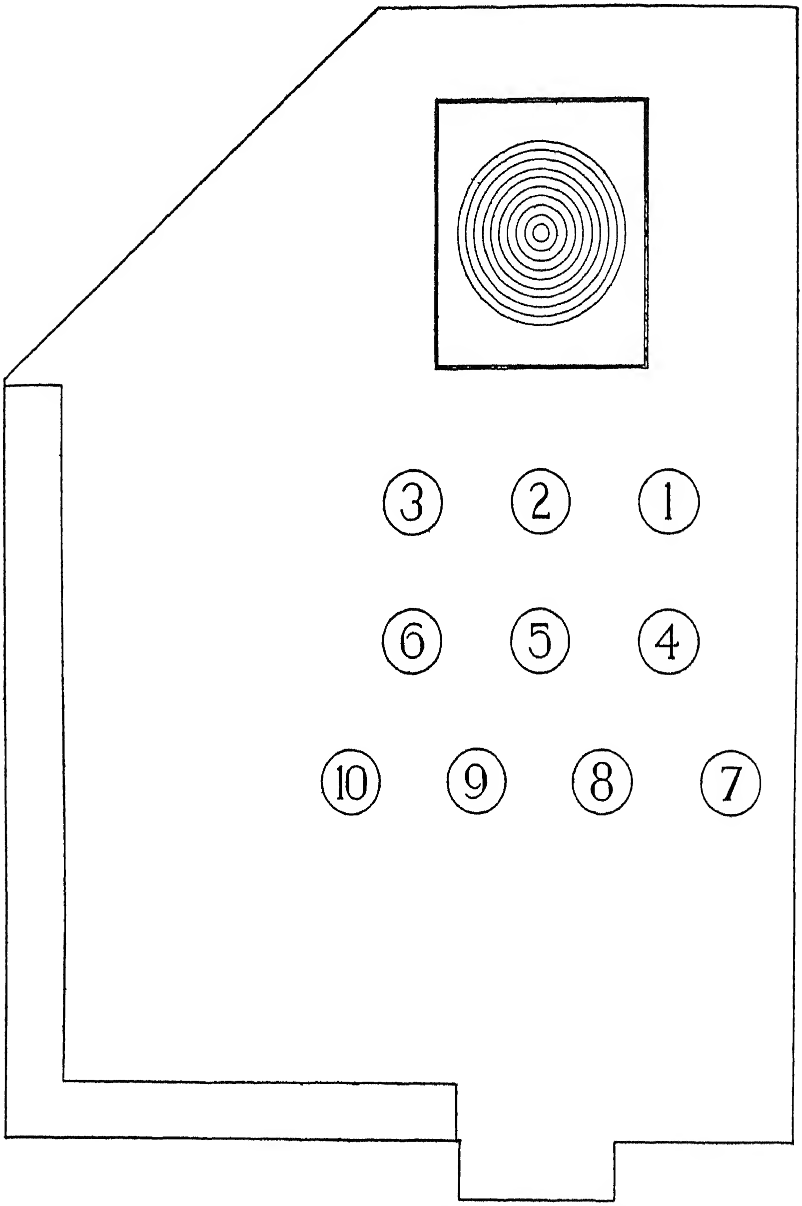

FIGURE 5. Floor plan of the room, and apparatus used in the ball tossing experiments.

The subjects of the experiment sat with backs toward the table on one or another of a series of ten stools set as shown and tossed steel balls over their shoulders aiming to hit as near the center of the table as they could. Their ears were stopped to prevent their knowing from sound whether a ball went too far or too short, to the right or to the left. Before the first trial of the first test they were directed to examine the table and its position in relation to the stools; and this examination was repeated before trials 11, 21, 31, etc., of all test series and before trials 1, 11, 21, 31, etc., of all practice series. Within each set of ten tosses the subject was required to face the opposite wall. Both test series and practice series were made up of sets of ten tosses, one from each stool in a random order. The program was:

Initial test with the left hand	40	tosses
Initial test with the right hand	40	"
Practice with the right hand	80	"
Intermediate test with the right hand	10	"
Practice with the right hand	80	"
Intermediate test with the right hand	10	"
Practice with the right hand	80	"
Intermediate test with the right hand	10	"
Practice with the right hand	80	"
Intermediate test with the right hand	10	"
Final test with the right hand	40	"
Final test with the left hand	40	"

In all the test series and in the *No Aid* practice series, the subject knew nothing from vision of the result of any of his tosses except that very wild tosses, such as caused the ball to fall to the floor and be recovered by the experimenter, sometimes resulted in his seeing the ball rolling back on the floor.

In the practice series *With Aid*, the result of each toss was signalled to the subject by the lighting of a number (10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0) on the wall which he faced, about

$4\frac{1}{2}$ seconds after his toss was made. 10 signified a bull's eye; 9, a toss within the second ring; 8, a toss within the third ring, and so on. 0 was the score for a toss that was outside the outermost ring. The scoring recorded where the ball finally went, not where it first hit. A ball which hit on a metal ring itself might, after bounding, land nearer to or farther from the center. The light was thus occasionally misleading.

The subjects consisted of four groups of eight individuals each. Two groups had aid in the form of the announcement of the score after each toss in the practice series. The other two, called *No Aid* groups, had only the aid given by

TABLE 90

TOSSING BALLS AT A HORIZONTAL TARGET: SCORES ATTAINED IN TESTS AND PRACTICES, 320 PRACTICES

No Aid Group	Initial Test	Practice I a	Practice I b	Intermediate Test	Practice II a	Practice II b	Intermediate Test	Practice III a	Practice III b	Intermediate Test	Practice IV a	Practice IV b	Intermediate Test	Final Test
Bar	52	48	31	0	62	23	5	42	18	5	41	11	4	11
Sa	62	35	31	16	95	112	24	91	102	34	108	89	25	144
Ho	76	62	76	5	69	85	21	83	103	32	104	80	13	112
Bo	49	99	54	4	35	20	9	27	20	3	12	25	4	28
Ru	122	71	135	32	81	103	21	134	132	14	118	105	40	102
Ke	61	116	90	13	52	27	5	57	53	12	40	49	8	78
At	81	71	95	7	41	48	18	79	64	22	108	83	10	112
Be	36	45	34	0	32	72	20	50	31	2	23	63	18	152
Sum	539	547	546	77	467	490	123	563	523	124	554	505	122	739
x4				308			492			496			488	
With Aid Group														
Fo	46	17	22	0	10	42	18	100	143	51	149	150	29	152
Wo	27	25	67	0	64	109	18	87	129	56	112	138	29	108
Sm	102	108	91	34	149	129	26	158	185	36	152	130	37	159
Ro	79	70	94	26	108	86	40	113	135	25	110	106	38	86
Ba	64	60	64	19	92	79	11	106	74	17	79	74	17	79
Wa	39	49	125	32	72	149	31	138	147	29	159	153	34	131
Sn	79	90	116	40	153	163	43	127	148	30	93	105	28	122
Da	124	54	59	2	50	58	11	54	50	14	73	58	15	43
Sum	560	473	638	153	698	815	198	883	1011	258	927	914	227	880
x4				612			792			1032			908	

the periodic examinations of the table, by sounds not excluded by the mufflers, by vision occasionally as noted above, and possibly by other cues from the experimenter's behavior.

We were concerned primarily to prevent all subjects, *With Aid* and *No Aid*, from knowing the *direction* of any of their errors, and to give the *With Aid* group much more satisfaction at successes than the *No Aid* group. These ends were attained, at least approximately. Except for a few tosses so wild that the ball hit the side wall, the subjects could not tell whether a shot was too short or too long, too much to the right or too much to the left. The *No Aid*

TABLE 91

TOSSING BALLS AT A HORIZONTAL TARGET: SCORES ATTAINED IN TESTS AND PRACTICES, 240 PRACTICES

	Initial Test	Practice I a	Practice I b	Intermediate Test	Practice II a	Practice II b	Intermediate Test	Practice III a	Practice III b	Intermediate Test	Final Test
No Aid Group											
Mu	13	12	10	5	31	22	7	52	45	6	36
Ha	107	126	126	33	125	135	48	116	165	25	120
Gr	81	74	79	7	108	127	21	121	84	24	138
Se	71	48	64	15	124	99	15	117	121	30	125
Sh	76	36	20	3	19	7	1	11	10	1	7
Jo	104	94	107	38	156	129	31	143	150	41	143
Pl	120	69	22	8	13	47	6	37	44	12	58
Wa	117	81	72	30	89	75	5	66	67	16	130
Sum	689	540	500	139	665	641	134	663	686	155	757
x4				556			536			620	
With Aid Group											
Mi	58	69	75	9	87	89	36	122	108	36	142
Jo	43	50	69	20	50	68	22	68	46	20	52
Bu A	33	24	35	18	42	31	9	23	34	9	43
Bu L	36	67	62	21	78	82	23	114	143	35	133
Bus	90	92	136	34	71	138	46	122	145	29	132
Ly	138	133	160	27	165	170	49	144	155	31	159
Hal	30	29	29	4	27	63	12	56	85	14	64
Sh	88	62	51	13	70	88	25	90	110	28	65
Sum	516	526	617	146	590	729	222	739	826	202	790
x4				584			888			808	

individuals occasionally felt chagrin at the sight of a ball rolling on the floor, and some of them possibly could distinguish through the muffler the clang of the ball hitting the steel rings, as distinguished from other sounds, but they lacked the satisfaction of knowing that a shot was very good from seeing 10 or 9 or 8 or 7 or 6 flash out.

Two of the groups had 320 practices, as in the program above. For the other two the practice was cut to 240 tosses. The facts appear in Tables 90 and 91.

In the longer series the average gain from initial test to final test was 40 for the *With Aid* and 25 for the *No Aid.* In the shorter series the corresponding figures are 34 and 8½. The probable errors are, respectively, 14, 12, 12, and 11. The average superiority of 20 or 218% for the *With Aid* is thus not very reliable, but it did not seem wise to use our time in extending the experiment with other groups to secure more certain results.

Experiment 48

LEARNING TO EXERT SPECIFIED PRESSURES WITH A SMEDLEY DYNAMOMETER, WITH ONE QUICK SQUEEZE

Twelve individuals were tested with a series in which they tried to squeeze 4 kg., or 8 kg., or 12 kg. at command, there being twenty-four attempts at each made in a mixed order. Each individual was first given a general notion of how hard to squeeze by being told the amounts in kg. of a slight, a moderate, and a hard squeeze which he made. After the test he was given similar series with aid in the form of the announcement of *Right* or *Wrong* according as his squeeze was within 1, 1, and 2 kg. of 4, 8, and 12 kg. respectively. The direction of his error he was never told.

The score in the initial test averaged 24% right. In the first round of training it rose to 37%; in the second it was 48%; in the next it was 50%; and in the next it was almost 60%. Thereafter there was no demonstrable gain. The attainment of this precision was, however, conditional

upon the short-lived influence of the reward and punishment. In the final test with no aid, the percent fell to 35. (Some of the twelve individuals had continued their practice for five more rounds, but with no demonstrable gain.) The gain of 11% has a probable error of 6. The gain of 23% (from 37% to 60%) with aid has a probable error of 7.

There was thus rapid gain under the circumstances of incessant guidance by announcement of *Right* or *Wrong*, but the permanent influence of this was less and not so certain.

How far the gain is due to a strengthening of the connections between the three commands and responses producing more suitable degrees of pressure in general, and how far it is due to ideas such as, "This squeeze deliberately made much harder than those which I have been making is right," is not clear.

We therefore repeated Experiment 48 with fourteen other individuals, all educated adults. The program for all was the same, a test of 72 pressures with no aid, four practices of 72 pressures each (24 of each sort) with announcement of *Right* or *Wrong*, followed by a test of 72 pressures with no aid. The results appear in Table 92. Each test or practice period is scored separately for the first and second 36, between which the subject had a short rest.

The score in the initial test averaged 12% right. In the first round of training it rose to 29%; in the second it was 38%; in the third it was 36%, and in the fourth, 44%. In the test it fell back to 38%. The gain from the initial to the final test was 26% $\pm$ 4 (P.E.).

The fact of rapid gain under the conditions of training is thus confirmed, and the more permanent retention of part of it is made reasonably certain and measured more reliably.

Combining the facts for the two groups of subjects with equal weight we have 18, 33, 43, 43, 52, and 36½ as the successive percents correct. The gain of 18½ has a probable error of 3.6.

The extent to which the rewards have power otherwise than by informative ideas about one's squeezes may be estimated by segregating the records of those individuals who at the start made all or nearly all their squeezes much too weak (or too strong). The improvement of these individuals may be due in whole or in part to informative ideas. If a person's record ran 0, 0, 0, k, k + a, k + a, k + a, k + a, k + a, k + a, k + a − b, and k + a − b − c, we should infer that improvement from 0 to k + a was wholly due to such. Some of their records (e.g., those of Du, Ja, and Wu) are like this, but others (e.g., those of Moo and Ri) show gain after the individual's constant error is overcome, and still others show a rise from zero only to relapse again (nearly or quite to zero as in the case of Go and Ke).

The presence of ideas that one needs to squeeze much harder, or the like, is then inadequate to account for all the facts. Gain due to such an idea alone should come quickly and remain fairly constant during the balance of the practice.

The individuals who had ten or more right out of 72 in the initial test and ten or more right in the first half of

TABLE 92

NUMBER OF SQUEEZES CORRECT (I. E., WITHIN CERTAIN LIMITS OF ERROR) OUT OF 36, IN SUCCESSIVE TRIALS WITH THE DYNAMOMETER: 14 ADULT SUBJECTS

	Initial Test		Practice Periods 1		2		3		4		Final Test		Gain
	A	B	A	B	A	B	A	B	A	B	A	B	
Bo	16	14	14	19	18	18	16	12	11	4	14	13	−3
Du	0	0	0	6	20	11	2	1	22	15	0	2	2
Go	0	0	0	1	3	18	19	6	3	1	5	1	6
He	9	2	12	6	19	14	14	13	22	21	19	20	28
Ic	11	14	22	21	18	11	18	26	30	24	25	10	10
Ja	0	0	0	0	12	13	10	13	4	13	18	14	32
Jo	16	5	19	18	14	12	8	17	25	20	22	15	16
Ke	1	0	0	0	16	14	5	8	0	0	0	0	−1
Moo	0	1	0	0	7	19	22	22	26	27	27	16	42
Moo2	0	2	18	21	11	19	11	19	17	17	18	17	33
Mor	13	0	12	18	0	14	0	0	5	15	6	5	−2
Re	17	1	25	29	17	29	28	28	30	31	18	29	29
Ri	0	0	9	23	3	4	4	18	20	16	22	18	40
Wo	0	0	0	2	14	15	17	23	9	18	19	15	34
Sum	83	39	131	164	172	211	174	206	224	222	213	175	
Av.	9		21		27		27		32		28		19±3
Percent correct	12		29		38		38		44		38		26±4

the first practice period were not in a position to be much helped by ideas about what a successful 4 or 8 or 12 kg. squeeze feels like in comparison with the squeezes which they had been making. Such individuals do, however, improve. We show in Table 93 the records of all such taken from Table 92 and also from the records of the twelve earlier subjects.*

TABLE 93

RECORDS OF SUBJECTS WHO HAD 10 OR MORE CORRECT IN THE INITIAL TEST AND 10 OR MORE CORRECT IN THE FIRST HALF OF THE PRACTICE PERIOD

	Initial Test		Practice Periods 1		2		3		4		Final Test		Gain
	A	B	A	B	A	B	A	B	A	B	A	B	
*Dr	7	21	21	30	22	14	20	26	27	31	8	10	−10
Dru	13	1	17	24	18	22	29	25	24	30	24	31	41
Fa	6	11	12	7	11	16	19	15	23	15	1	1	−15
*Le	14	25	12	26	24	25	21	19	28	26	21	24	6
*Ne	11	13	16	18	23	17	12	27	17	2	6	12	−6
*Sp	12	2	20	13	10	20	10	14	25	18	15	19	20
*Hu	9	1	14	7	21	24	17	5	16	17	7	1	−2
Bo	16	14	14	19	18	18	16	12	11	4	14	13	−3
He	9	2	12	6	19	14	14	13	22	21	19	20	28
Ic	11	14	22	21	18	11	18	26	30	24	25	10	10
Jo	16	5	19	18	14	12	8	17	25	20	22	15	16
Mor	13	0	12	18	0	14	0	0	5	15	6	5	−2
Re	17	1	25	29	17	29	28	28	30	31	18	29	29
Sum	264		452		451		439		537		376		
Av.	20		35		35		34		41		29		9±3
Percent correct	28		48		48		47		57		40		12±4

The average gain from initial to final test for these thirteen is 12% (from 28% correct to 40% correct) with a probable error of ±4.

There is no need to multiply experiments of the type of Experiments 43 to 48. Anyone interested can now make such in any field of judgment or action, equalizing congruity, consummatoriness, etc., and reducing the opportunity to repeat or rehearse the correct connection.

So far as frequency, recency, intensity, congruity, finality, etc., are concerned, we have to arrange matters (1) so

* In some of these (those marked with an asterisk) the score in the test after the four practice periods is estimated from that of a test taken after more practice periods than that. The method of estimating was to take the final test or the fifth practice period, whichever was the lower.

that the subject learns nothing about his response save that it is or is not satisfying, (2) so that nothing happens that can differentiate one connection from another before the satisfying or non-satisfying after-effect, and (3) so that nothing happens that can differentiate one connection from another after the satisfying or non-satisfying after-effect, except what is caused by the after-effect itself.

I have sought to devise experiments in which the connections which are strengthened are absolutely free from any such opportunities. The general plan is to have, in addition to the connections ostensibly rewarded and learned, certain others which the learner may strengthen without knowing that he does so, or even that they exist. He cannot repeat or rehearse the connection because he does not know what it is. These experiments and their results are presented in the next chapter.

CHAPTER X

The Influence of the After-Effects of a Connection When Opportunities to Repeat or Revive It or Any Equivalent or Substitute for It Are Excluded

Consider the following experiment in which the ostensible learning is to form connections between cards with four lines on each and correct judgments of which line is longest, whereas the hidden learning is to connect the sight of any card with a blot on it with the tendency to judge the line at the extreme left to be longest, and the like.

The subject judges which one of four lines is longest. He is instructed as follows:

> I shall show you large cards like this. Each has four lines which we call, beginning at the left, 1, 2, 3, and 4. You will compare the four lines as to length and state the number of the one which you think is the longest. If a line is broken by white strips across it, disregard these, and use as its length the distance from one end to the other. The differences in length are very, very small, and consequently your judgments at the beginning may seem to you to be mere guesses.

The cards are then displayed; the subject is allowed about five seconds to make his judgment; the experimenter then turns down the card, records the judgment, and announces *Right* or *Wrong*.

The series of cards is so constructed that all the differences are utterly indistinguishable, being zero or less than ½ mm., but in a card which has one line thicker than the others, line 3 is always right. In a card which has one line cut by two white strips, line 2 is always right. In a card which has a blot or imperfectly drawn line, line 1 is right. For the other sorts of cards used, there is also always some feature by connection with which correctness of response

can be attained. Of all this the subjects know nothing at the start of the experiment, and some of them never learn anything of it. We limit our consideration to them. Of them, some persistently judge by trying to discern some difference in the lengths of the lines after a careful inspection of each of the four. But this involves a painful eye-strain and many subjects use the license permitted by the instructions and just give a general look at the card and guess. With the guessing there may be combined various false ideas—that the numbers come in certain sequences, or that the thick line is the longest, or that the line to the right of the line cut by two white strips is the longest, etc., etc. These false ideas do no harm to our experiment.

Whatever the subjects do, so long as they do not learn the right system or any feature of it, the connection between the external situation of a card with one line thicker and the response, 3, will be followed by a *Right*, and the connection between that external situation and any other response (1, 2, or 4) will be followed by a *Wrong*. But the subjects will not know this and consequently will not repeat to themselves *Card with thick line, 3,* after they hear the *Right*. If then these subjects learn, that is, improve in their percentage of correct responses, they do so with no aid from inner repetition or rehearsal of the connections which have been followed by satisfiers.

If these subjects do not learn, that will not prove that learning requires inner repetition or rehearsal. The crucial feature in the external situation may not "belong" sufficiently to the response to be connected with it in the brain. Although the eyes see it, the brain may shunt it off to some limbo for irrelevant elements. But if they do learn, that will prove that learning does not require repetition or rehearsal.

In such an experiment we have a certain feature of the external situation followed by certain responses each a certain number of times, and with certain specified after-effects controlled by the experimenter, and without interference by inner repetition, rehearsal, or recall by the

subject. If we equalize frequency, any balance of strengthening or weakening must be due to the after-effects.

Experiment 49

Experiment 49 was as follows: An individual was tested with four vocabulary tests (each containing 100 rare English words) of the selective type shown below. In three of these (A I, A II, and A III) the correct response occurred 0 times in the first place to the left, 10 times in the second place, 20 times in the middle place, 30 times in the fourth place next to the right, and 40 times at the extreme right. In the fourth test, B I, the correct response occurred indifferently as regards position. The individual tested knew nothing about the method of construction of the tests. After he had been thus tested, he was trained by four repetitions each of A I and A II. In those, as soon as the subject had underlined the word he chose as right, the experimenter announced *Right* or *Wrong*, and the subject at once proceeded to underline a word in the next line. After this training the subject was retested as before.

Look at the first word in line 1. Find the other word in the line which means the same or most nearly the same. Draw a line under it. Do the same in lines 2, 3, 4, etc. Lines *A*, *B*, and *C* show the way to do it. Do all the lines. When you do not know, make a guess. Draw a line under some word in every line.

A. beast	afraid. . . .words. . . .large. . . .animal. . . .bird
B. baby	cradle. . . .mother. . . .little child. . . .youth. . . .girl
C. raise	lift up. . . .drag. . . .sun. . . .bread. . . .deluge
1. acanthus	angular. . . .drug. . . .hip disease. . . .fish. . . .plant
2. angina	eel. . . .needle. . . .inflammation. . . .squint. . . .helmet
3. apprise	scare. . . .poach. . . .elevate. . . .lever. . . .inform
4. atrium	cave. . . .prologue. . . .check. . . .hall. . . .vine
5. barbette	beard. . . .parapet. . . .haircut. . . .small thorn. . . .bush

The training results in an increase of right responses, and, consequently, in an increase in the frequency of sequences of the form, *Read a line* $\rightarrow$ *underline a word at or*

near its right end and a decrease in the frequency of sequences of the form, *Read a line* → *underline a word at or near its left end.* The former sort of sequences are also more often followed by the satisfying *Right.*

In some subjects this happened without any idea that the right word was any more often in one portion than another. In what follows we shall limit ourselves to the records from these subjects, who answered *No* to 1 and 4 of the following questions:

1. In the experiments in learning the meanings of words, did you come to think that words in certain positions were never right or very rarely right?..
2. If so, which positions were they?....................................
3. In the tests at the end of the experiment, did you consciously avoid underlining words in these positions?....................................
4. Did you come to think that words in certain positions were very often right?..
5. If so, which positions were they?....................................
6. In the tests at the end of the experiment, did you consciously favor underlining words in these positions?....................................

The questions of importance are: first, whether the tendency to underline at the left end was weakened and the tendency to underline at the right end was strengthened in A III and B I, as a result of the training; and second, whether the change was greater than the change in frequency can account for.

The answer to the first question is *Yes.* The eleven subjects who reported that they had not noticed that the words in one position in A I and A II were more or less often right than words in another, and did not consciously favor any positions in the tests, did underline words in positions 1 and 2 less often in the tests with A III and B I after the training with A I and A II than in the tests before the training; and they underlined words in positions 4 and 5 more often. The change was as follows:

Positions	1	2	3	4	5
Occurrences before training	530	413	427	368	462
Occurrences after training	400	408	454	447	491
Change	−130	−5	+27	+79	+29

The details appear in Table 94.

How far this change can be credited to the greater frequency during the training with A I and A II of the connections which dispose a person to underline the left positions less and the right positions more, and how far it should be credited to the more frequent attachment of annoyingness to the former and satisfyingness to the latter, is not revealed by the experiment. The frequencies in question were as follows: The responses by underlining words 1, 2, 3, 4, and 5 in A I and A II were, respectively, 1918, 1911, 2150, 2250, and 2771 in number, up to the beginning of the final tests.

What we have learned concerning the influence of repetition pure and simple makes it extremely unlikely that the increased tendency to underline at the right in the final tests was due to the greater number of such underlinings during the training, but we have made a special experiment (50) to measure the influence of the frequency factor, with no influence of reward.

Experiment 50

Nineteen subjects served in this experiment. The responses by underlining words in positions 1, 2, 3, 4, and 5 in A I and A II during the training were, respectively, 2694, 2496, 3083, 3243, and 3512 in number (there being 172 omissions by carelessness or lack of time). The proportions are almost the same as in Experiment 49, the percentage which 4 plus 5 is of 1 plus 2 being 130. The change from the tests before to the tests after training was practically *nil*. In B I the numbers were, for the five positions:

	1	2	3	4	5	Omissions
Before training	366	332	412	373	412	5
After training	361	331	433	356	414	
Change	−5	−1	+21	−17	+2	

TABLE 94

NUMBER OF WORDS UNDERSCORED IN EACH POSITION BEFORE AND AFTER TRAINING

Subject	Number Right		Number of Words Underlined in Each Position in A I and A II										Number of Words Underlined in Each Position in A III and B I									
	Before Training	After Training	Before Training					After Training					Before Training					After Training				
			1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
3	52	59	50	43	36	28	43	35	35	29	52	49	61	30	33	25	51	45	37	31	35	52
10	62	144	54	23	46	25	52	12	22	36	59	71	45	34	47	36	38	23	37	50	47	43
11	41	73	41	35	35	36	53	24	35	37	40	64	42	32	38	40	48	10	37	54	62	37
14	47	100	59	39	33	34	35	20	25	45	52	58	70	48	29	29	24	41	43	35	35	46
15	61	89	41	31	34	40	54	26	34	50	37	53	47	27	36	45	45	43	31	40	38	48
16	46	89	61	41	43	35	20	32	27	44	51	46	47	41	53	29	30	39	38	52	39	32
17	54	127	47	45	28	39	41	16	20	45	48	71	39	52	41	37	31	35	40	40	49	36
19	112	160	23	29	41	43	64	11	21	44	54	70	35	32	37	39	57	36	32	37	42	53
22	88	130	36	41	31	42	50	13	27	46	53	61	49	30	40	31	50	50	35	35	30	50
23	43	93	75	38	31	27	29	18	32	36	58	56	48	43	40	25	44	33	36	40	38	53
24	55	110	45	39	32	45	39	10	36	40	46	68	47	44	33	32	44	45	42	40	32	41
Sum	661	1174	532	404	390	394	480	217	314	452	550	667	530	413	427	368	462	400	408	454	447	491

In A III, four of the nineteen did not have time to complete the test before training. If we assume that these four would have had numbers in the five positions in the same proportions as the other fifteen individuals, the numbers for the four positions are:

	1	2	3	4	5
Before training	321	367	448	434	330*
After training	288	382	441	433	356**
Change	−33	+15	−7	−1	+26

* 15 omissions being divided 3, 3, 3, 3, and 3.
** 41 omissions being divided 8, 8, 9, 8, and 8.

By this computation, the change for both tests together is —24 for positions 1 and 2, and +10 for positions 4 and 5, giving a balance of 34 for 19 subjects, or fewer than 2 per subject. In the experiment with reward, the balance was 243 for 11 subjects or 22 per subject. If we omit the four incomplete records for A III we have:

	1	2	3	4	5
Before training	253	290	354	343	260
After training	225	315	344	334	282
Change	−28	+25	−10	−9	+22

By this computation the change for both tests together is —9 for positions 1 and 2, and —2 for positions 4 and 5, with a balance of approximately zero.

By the average of the two computations the balance is 1 per subject, compared to 22 per subject when reward operated as well as frequency.

Twelve of the nineteen individuals answered *No* to questions 1 and 4 of the following questions.

1. In the experiments in learning the meanings of words, did you come to think that words in certain positions were never right or very rarely right?
   ....
2. If so, which positions were they?..................................
3. In the tests at the end of the experiment, did you consciously avoid underlining words in these positions?....................................
4. Did you come to think that words in certain positions were very often right?..

5. If so, which positions were they?....................................
6. In the tests at the end of the experiment, did you consciously favor underlining words in these positions?..

Of the seven who said *Yes* to either 1 or 4, two were wrong in their notions, one thinking that the first word was very often right, the other that the middle word was very often right. Of the remaining five, all but one replied *No* to questions 3 and 6. That one replied, "No.—. No. Yes. About the middle or last word of each list. I think I did." If her records are omitted, the balance in favor of positions 4 and 5 is reduced by 6, since she shifted from 58 to 59 underlinings of 1 and 2 and from 70 to 65 underlinings of 4 and 5.

By the courtesy of Miss Alice White we have data from eighteen subjects who were tested with B I and B II before

TABLE 95

THE INFLUENCE OF FREQUENCY OF UNDERLINING IN CERTAIN POSITIONS IN A I AND A II UPON THE TENDENCY TO FAVOR THOSE POSITIONS IN B I AND B II. FREQUENCIES FOR ALL POSITIONS IN TRAINING AND TESTS

	Positions				
	1	2	3	4	5
Training 1 A I	197	233	331	434	505*
A II	178	260	354	458	550
Training 2 A I	102	243	325	483	647
A II	92	207	357	509	635
Training 3 A I	59	223	343	503	672
A II	41	203	354	515	687
Training 4 A I	13	198	367	506	716
A II	27	198	360	506	709
Training Total	709	1765	2791	3914	5121*
Test with B I and B II before training	626	696	766	693	819
Test with B I and B II after training	549	682	913	759	697
Change	−77	−14	+147	+66	−122

* One subject missed the first trial with the A I set. Hence the totals are 1700 for that trial and 14,300 for all trials.

and after four repetitions of A I and A II, in which the subjects underlined in position 5 ten times as often as in position 1 and in position 4 more than twice as often as in position 2, but were not rewarded therefor. The results are shown in Table 95.

We may use the records of Experiment 49 itself in a subtle way to test the potency of the *Right* to strengthen the tendency to underline at one end of the line rather than at the other under the conditions of the experiment without any awareness on the part of the subject that any such tendency is being learned or exists at all. This way also frees the influence of after-effect from that of repetition. We may consider only the initial test with A I, the initial test with A II, the first trial of A I with announcements of *Right* and *Wrong* and the first trial of A II with announcements of *Right* and *Wrong*. These four occurred in that order, and the first practice trial with A II thus differs from the first practice trial with A I in having been preceded by (on the average) 150 instead of 50 instances, amongst which underlinings at the right (positions 4 and 5) had been rewarded on the average seven times as often as underlinings at the left (positions 1 and 2). It does not differ in having an appreciably greater number of the preceding underlinings in positions 4 and 5 than in positions 1 and 2. For all the individuals together the underlinings up to the beginning of the first practice trial of A I showed a ratio of $\frac{\text{Positions 4 and 5}}{\text{Positions 1 and 2}}$ of 1.00, and up to the beginning of the first practice trial of A II a ratio of 1.01.

If, then, there is a tendency for the first practice trial of A II to differ more from the first test with A II in the direction of underlinings toward the right than the first practice trial of A I does from the first test with A I, this must be due to the excess of 100 instances amongst which underlinings of 4 and 5 had been rewarded seven times as often as underlinings of 1 and 2.

The facts show such a tendency. For the summed rec-

ords of 22 individuals * the underlinings in the first practice trial of A II were in positions 4 and 5 twenty-four times oftener, and in positions 1 and 2 twenty-seven times less often, than in the first test with A II, making a balance of fifty-one attributable to the effect (subject to correction for chance variations). For the similar records of the same individuals in the first practice trial of A I compared with those in the first test with A I, the balance is 0.**

Experiment 51

Experiment 51 was like Experiment 49, except that the training material consisted of 200 Spanish words arranged in two leaflets C I and C II, each word being followed by five English words as shown in the sample below. The right one of the five occurred in positions 1, 2, 3, 4, and 5 with frequencies of 10, 15, 20, 25, and 30, respectively. As tests before and after the training, a similar blank (C III) was used and also blanks A I and B I. Of the nine subjects, eight reported *No* as their answers to 1 and 4 of the questions on pages 213 f. The other subject thought that words in position 1 were usually wrong and allowed for this to some extent in the late test. His record is not used in what follows.

61. ahorro	awful....thrift....hatred....vicious....tumult	......	61
62. ajeno	tricky....vivid....groveling....upstart....strange	......	62
63. alacena	lobule....pool....feathery....spoil....cupboard	......	63
64. altanero	gross....tall. ..torpid....haughty....righteous	......	64
65. amprar	secure....fasten....borrow....restore....debate	......	65
66. ancho	jest ...whirling....circle....wide....today	......	66
67. antes	rather.. .reaching....spring....tube....horn	......	67
68. anzuelo	comrade....mutiny....fishhook....sailcloth....timidly	......	68
69. aojo	juice....gorgeous....reach....help....witchery	......	69
70. apagar	alienate....grieve....annoy....quench....effect	......	70

* We may use all our subjects here, since no one of them surmised anything about the constitution of the series before the end of trial 1 with A I and A II.

** The difference of 51 in balance has a mean square error of 54, that is, as large as itself, and we shall need to corroborate it. In this, as in almost all the experiments of this section, we are working with influences which we know to be slight. The satisfyingness "belongs" essentially to the choice of a certain word, and only incidentally to the turning of the eyes toward a certain place or the drawing of a mark at that place.

The training with C I and C II was continued long enough to produce substantial improvement.* This training with C I and C II resulted in a notable weakening of the tendency to underline at the left and strengthening of the tendency to underline at the right of the Spanish blank (C III), and in a similar but slighter change in the tests with English words A I and B I. The change for C III was as follows:

Position	1	2	3	4	5
Occurrences before training	220	197	165	120	98
Occurrences after training	149	173	153	154	171
Change	−71	−24	−12	+34	+73

The change for A I and B I combined was as follows:

Position	1	2	3	4	5
Occurrences before training	330	269	333	315	353
Occurrences after training	276	272	336	350	366
Change	−54	+3	+3	+35	+13

In this experiment a control was supplied by eight subjects who were tested with C III and A I before and after training with B I and B II. In B I and B II no relation existed between position and correctness, and no underlining was done, the subject's response being made by writing the word he thought right in a space provided for the purpose. The changes for these eight subjects in C III were +20, —6, —0, —13, and —1 for positions 1, 2, 3, 4, and 5, respectively. Their changes in A I were +48, —8, —54, —6, and +20 for positions 1, 2, 3, 4, and 5, respectively. There was thus no gain for positions 4 and 5.

By reason of a certain feature of the subjects' responses in these vocabulary experiments, we may show that the frequency of responding to the situation of choosing a word from five in one of these vocabulary test-blanks by underlining at the right cannot account for the increase in the tendency to do so in our experiments with announcement of *Right* or *Wrong*. The feature in question is a

* As a rule, for eight periods of fifty minutes each.

tendency in early trials to check the first or second word more often than the third or fourth or fifth in cases where one has no knowledge at all of the meaning of the given word. Because of this, the total frequency of underlinings in positions 4 and 5 does not reach that of underlinings of 1 and 2 until a number of trials have been completed. So we are able to measure the tendency to favor positions 4 and 5 at a time when the force of frequency does not favor them. The method of the check is as follows in the case of learning to choose the right meanings for the two hundred Spanish words:

We make a cumulative count of the subject's responses until we reach the trial where his percent of underlinings in positions 4 and 5 is as great as his percent of underlinings in positions 1 and 2. For example, subject N in eight trials with C I and C II had a total of 652 out of 1600 underlinings in positions 1 and 2 and 643 in positions 4 and 5. When trial 9 is counted in, the figures are 710 and 741 out of 1800. Up to trial 9 then, positions 4 and 5 had no advantage from frequency. We then compute the distribution of his responses in trial 9 to all the words save those already learned. A word was counted as learned beginning with the first of a series of uniformly correct responses, or of a series broken only after many correct responses by such an error as seemed surely to be due to a lapse of the subject. We compute also the distribution of his responses in Test I to all the words save those already learned. In the case of subject N, these two distributions were as shown below.

		Test I	Trial 9
Number in position	1	49	22
	2	41	16
	3	27	30
	4	36	24
	5	37	34
Number already known		10	74
Percent in positions 1 and 2		47.4	30.2
4 and 5		38.4	46.2

Subject N thus had come to favor positions 4 and 5 at a

time when frequency to date had been slightly in favor of positions 1 and 2.*

Similar facts for subject R are that the cumulative count at the end of trial 3 shows 248 underlinings out of 600 in positions 1 and 2 and 233 in positions 4 and 5. The distributions for Test I and trial 4 are:

	Test I	Trial 4
Number in position 1	73	16
2	41	29
3	38	37
4	23	53
5	18	44
Number already known	6**	21
Percent in position 1 and 2	58.7	25.1
4 and 5	21.1	54.2

In the same manner we obtain the results shown in Table 96 for the six other subjects. It is clear from these facts that the increase in the tendency to underline unknown words in positions 4 and 5 on the C I and C II blanks is largely independent of frequency. The increase up to the trials used in Table 96 cannot be caused by frequency at all but only by the greater satisfyingness consequent upon underlinings in positions 4 and 5. Probably the same holds true of the continued increase in later trials, and of the tendency as transferred to the third booklet of Spanish words (C III) and as transferred in less degree to booklets of the same size, shape, and arrangement, but with rare English words.

Experiment 52

Five subjects were used in an experiment identical with Experiment 51 in all respects save that the training (eight trials with each of C I and C II) was not so long and the tests were CIII, A I, and A II. One subject answered y, 1, y, y, 5, n, to the questions on pages 213 f. Another subject

* In these computations, the cumulative count of frequencies does not include Test I.

** One line was omitted by mistake.

Table 96

THE CHANGES IN UNDERLINING FOR THE UNKNOWN WORDS IN C I AND C II (SPANISH WORDS) FROM THE INITIAL TEST TO THE TRIAL UP TO WHICH THE FREQUENCY FOR POSITIONS 1 AND 2 EQUALLED OR EXCEEDED THE FREQUENCY FOR POSITIONS 4 AND 5

	Subjects															
	H		M		N		P		Ra		Ro		Sp		St	
	In.	Tr.3	In.	Tr.4	In.	Tr.9	In.	Tr 6	In.	Tr 6	In.	Tr 4	In.	Tr.17	In.	Tr 16
Number in position 1	62	34	57	20	49	22	58	23	71	21	73	16	42	20	52	14
" " " 2	30	30	31	30	41	16	52	21	42	22	41	29	70	28	36	12
" " " 3	38	26	33	28	27	30	37	22	29	28	38	37	47	37	42	14
" " " 4	29	38	38	41	36	24	29	19	25	18	23	53	25	46	29	26
" " " 5	36	52	25	37	37	34	15	26	27	12	18	44	15	30	28	48
Number already known	5	10	16	44	10	74	9	89	5*	99	6*	21	1	39	13	86
Percent in positions 1 and 2	47	34	48	32	47	30	58	40	58	43	59	25	56	30	47	23
" " " 4 and 5	33	47	34	50	38	46	23	41	27	30	21	54	20	43	30	65
Balance in favor of 4 and 5	27		32		25		36		18		57		49		59	
Frequency of 1 and 2	155		322		652		319		408		248		1211		1209	
" " 4 and 5	163		300		643		321		407		233		1209		1174	

* One line was omitted.

answered y, 1, n, y, 3 or 4, n. Their records are not used in what follows.*

The training, consisting of eight trials with C I and eight trials with C II, results, as in Experiment 51, in a strengthening of the tendency to underline at the right end in booklets C III, A I, and A II.

The change for C III was as follows:

Position	1	2	3	4	5
Occurrences before training	112	56	41	44	47
Occurrences after training	97	55	50	52	46

The change for A I and A II combined was as follows:

Position	1	2	3	4	5
Occurrences before training	158	104	113	98	127
Occurrences after training	145	104	110	105	126

Positions 1 and 2 lose 13 and positions 4 and 5 gain 6.

In two of these subjects we are able to apply the same check applied in Experiment 51 of measuring the change in the tendency to underline positions 4 and 5 rather than 1 or 2 from Test I to a point where the total number of

TABLE 97

THE CHANGES IN UNDERLINING FOR UNKNOWN WORDS IN C I AND C II FROM THE INITIAL TESTS TO THE TRIAL UP TO WHICH THE FREQUENCY FOR POSITIONS 1 AND 2 EQUALLED OR EXCEEDED THE FREQUENCY FOR POSITIONS 4 AND 5. SUPPLEMENT TO TABLE 96

	Br M		Pl	
	In.	Tr.8	In.	Tr.3
Number in position 1	41	24	74	19
2	25	31	33	21
3	24	19	25	11
4	23	20	19	26
5	34	19	22	16
Number already known	53	87	27	107
Percent in positions 1 and 2	45	49	62	43
4 and 5	39	35	24	45
Balance in favor of 4 and 5	−8		40	
Frequency of 1 and 2	611		177	
4 and 5	531		162	

* It would be allowable to use the second, since she did not consciously avoid position 1 or favor position 4 in the tests, thinking, as she said, "that they might be twisted."

underlinings to date was as great for 1 and 2 as for 4 and 5. This cannot be done for subject Ba because she knew about half the words at the start and so had more underlinings in positions 4 and 5 than in 1 and 2 from the start. The facts for Br M and Pl are shown in Table 97.

In addition to the evidence already given showing that the frequency of connections cannot have been the cause of the increased underlining at the right in Experiments 49, 51, and 52, we have that furnished by Experiments 53 and 54. The individuals who served as subjects in these experiments were of age, ability, and education comparable to those who served in Experiments 49, 51, and 52. They had had no previous experience with the vocabulary sheets.

Experiment 53

Eleven individuals were tested with A III and B I, before and after the following training: On eight sheets of vocabulary tests,* each containing 100 lines, each consisting of a word and five meanings, they wrote *C* after the meaning which they judged to be correct and drew a line under the word which contained a mutilated letter. The words containing mutilated letters occurred 0, 10, 20, 30, and 40 times in positions 1, 2, 3, 4, and 5, respectively. Consequently the underlining occurred in those positions with approximately those frequencies, since the mutilations were easy to see and were rarely missed. The eleven individuals showed the following frequencies of positions 1 to 5 for their wrong responses, before and after the training (page 223).

There was thus a total loss of 31 or 4% for positions 1 and 2 and a loss of 5 or 1% for positions 4 and 5.

The subjects were tested after the training also with B II. The results for it were, for positions 1 to 5 in order, 169, 179, 153, 151, and 142. If B I before the training is compared with B II after the training, there was a gain of 0 for positions 1 and 2 and a gain of 11 or 4% for positions 4 and 5.

* Four each of two sorts.

		Before Training	After Training	Gain
A III	1	236	211	−25
	2	181	192	+11
	3	149	178	
	4	143	150	+7
	5	99	88	−11
B I	1	206	173	−33
	2	142	158	+16
	3	142	156	
	4	151	148	−3
	5	131	133	+2
Total		1580	1587	

If we compare the frequencies in the different positions before and after the training, counting B I twice before training, we have:

	Before Training	After Training	Gain
1	648	553	−95
2	465	529	+64
3	433	487	+54
4	445	449	+4
5	361	363	+2
Total	2352	2381	

There was, by this count, a total loss of 3% for positions 1 and 2 and a total gain of 1% for positions 4 and 5.

Experiment 54

Eight other individuals were tested with A I and B I before and after training exactly like that just described except that the eight sheets used for training were different, including different forms, and had the mutilated letters occurring 10, 15, 20, 25, 30 times in positions 1, 2, 3, 4, and 5, respectively. They were also tested with B II before the training and with C I after the training.

The eight individuals showed the following frequencies of positions 1 to 5 for their wrong responses before and after the training:

		Before Training	After Training	Gain
A I	1	182	217	35
	2	89	125	36
	3	102	101	− 1
	4	92	82	−10
	5	90	47	−43
B I	1	138	177	39
	2	121	117	− 4
	3	97	103	6
	4	101	84	−17
	5	121	88	−33
B II	1	161	185	24
	2	137	145	8
	3	136	124	−12
	4	91	77	−14
	5	80	68	−12

There is thus a total gain of 138, or +8%, for positions 1 and 2, and a total loss of 129, or —8%, for positions 4 and 5.

If both experiments are considered together, there is a gain of 2% for positions 1 and 2 and a loss of 3% for positions 4 and 5. The greater frequency of underlining words at the right during the training had then no demonstrable influence upon the underlining done in the tests.

Experiment 55

Experiment 55 was similar in type to Experiments 49 and 51. Two multiple-choice vocabulary tests (called B I and B II) were constructed with rare English words in which the correct response words began with *b* very, very often (41 and 40 out of 100), with *s* or *t* very often (30 and 29 out of 100) and with *d, f, h, l, m, p, r,* and *w* in the balance of the two hundred. The other letters (*a, c, e, g, i, j, k, n, o, q, v, u, x, y,* and *z*) never were the initial letters of the correct responses. The subject responded by writing the word he chose. After a test with A I, C III, and B I, he was trained with B I and B II by the announcement of *Right* when he wrote the correct response and of *Wrong*

when he did not. After the training he was tested again as before. At the end of the experiment, he reported whether he had had any notion that words beginning with certain letters were very often right, and words beginning with certain other letters were very often wrong. No one of the eight subjects had had any such notions.

Although no awareness of any relation between correctness and the nature of the initial letter was reported, the tendency to choose and write words beginning with *b, s,* or *t* in the blanks A I and C III was apparently strengthened by the training with B I and B II. Using only the wrong responses in A I and C III, the number beginning with *b, s,* or *t* rose from 306 before training to 330 after training, whereas for nine control subjects who were trained with C I and C II it dropped from 304 to 297.* The average gain of 3 from the B I-B II training has a mean square error of 1.7. The average loss of —0.8 for the controls has a mean square error of 2.0. So the average difference of 3.8 has a probability of about one in ten of being due to chance.

We have made no additional experiments to separate the influence of the greater frequency of writing words beginning with *b, s,* and *t* from the influence of the rewards. It would require much time which will be better spent in other experiments.

The main purpose of Experiment 55 was to ascertain how subtly after-effect, or repetition, or both, would operate upon minor features of a response. An individual is rewarded for choosing one of five meanings for a word and writing it. Will a reward for choosing and writing a word that begins with a certain letter and the consequent later repeated choice and writing of that word cause him to favor words beginning with that letter for any line on any similar booklet given as a part of the same experimental situation?

It may be argued that a positive result in such an experi-

* The right responses are largely determined by knowledge possessed by the subjects before the experiment began, and so are better left out of account in our calculations.

ment proves too much, requiring that the strengthening influence of the sequent satisfying state operate upon features too subtle to be represented in the physiological events accessible to such influence. I am in sympathy with this criticism. However, it is a question of fact what connections do exist in the brain to be strengthened in any piece of behavior. When a word is chosen in these experiments, its length, harshness of sound, initial letter and the like may be represented in the object of physiological choice. Anything that has an existence as a modifiable feature of the neurone equivalent of a connection may conceivably be modified by the after-effect of that connection. These same considerations apply, but in a less degree, to Experiment 56.

Experiment 56

Experiment 56 was as follows:

The task throughout was to supply one letter for each dot to complete mutilated words like those shown below.

ab..
c.ap
d.ve
g..de
gen.s

Two hundred and fifty words were used in all. First there was a practice series of 10 words; then there was a test with 40 words; then training with a set of 160 words repeated 14 times or more, then a test with 40 words not used in the initial test or in the training. The two tests of 40 each were selected from 80 by chance to insure substantial equivalence in all essential respects. During the fore-exercise and the initial and final tests, no announcements of right or wrong were made (but during the training there were) the following directions being followed by the experimenter:

> Provide the subject with a pencil. Say, "You will write letters to complete words just as you did before, except that

now only certain words will be right. Some letters I shall call wrong even though they make a real word. You will not know at the start on what basis I call certain completions right and certain other completions wrong. And you may never know. You may or may not come to know about it as the experiment progresses. If you get any ideas about it, keep them to yourself. Say nothing to anybody about them. And do not think about these completions at all except when we are experimenting." Then proceed with words 1 to 160 saying *Right* when the right letter is put in place of the first dot and the word is a real word. Say *Wrong* when any other than the right letter is put in place of the first dot. If no completion is made in 5 seconds, say, "Do number . . ." (the next in order).

The basis for the announcement of *Right* and *Wrong* during the training was that a dot following an *a* must be filled by a *v*, a dot following a *b* must be filled by an *l*, a dot following a *c* must be filled by an *h*, and so on with *i* after a *d*, *a* after an *e*, *u* after an *f*, *r* after a *g*, *o* after an *h*, *n* after an *i*, *o* after an *l*, *i* after an *m*, *u* after *n*, *v* after *o*, *u* after *p*, *i* after *r*, *t* after *s*, *i* after *t*, *t* after *u*, *e* after *v* and *r* after *w*.

Eight subjects were used. Five of them had, by the time of the final test, learned more or less of the basis for the announcement of *Right* and *Wrong*. They are not considered in what follows. Three subjects showed by their records in the training and by their answers to questions 1, 2, and 3 below that they were entirely ignorant of the system.

1. In the learning to complete words by supplying letters, did you come to think that the last letter before the empty space had to be followed by a certain letter? If so, what letter did you think had to come after

a	l
b	m
c	n
d	o
e	p
	r
f	
g	s

h	t
i	u
	v
	w
	y

2. In the test at the end, did you consciously try to supply right letters?
3. Or did you, in the test at the end, put in any letters that made a word?

These three subjects improved from the first 160 to the last 160 of the training series from 53, 36, and 44 right to 98, 108, and 65 right, respectively. In the initial test of 40 they had 11, 9, and 8 right, respectively; in the final test of 40, they had 18, 19, and 10 right.* This average gain of 6.3 has a mean square error of about 2. There is thus no appreciable probability that it is due to chance.

As in all similar experiments, we have to consider the possibility that the strengthening of these tendencies (for the sight of a dot with *a* before it to evoke *v* more than it originally did, and the like) is due partly or entirely to such tendencies having operated frequently during the training rather than to their operation having been followed by *Right* (and to the operation of competing tendencies having been followed by *Wrong*) during the training.

Experiment 57

In Experiment 57, the same initial and final tests were given but the intervening training consisted of much repetition of the "right" responses plus some completions of the subject's own choice, with no announcements of right or wrong.

The sheets containing the 160 incomplete words now contained 160 lines each with four copies of the incomplete word. In the first three of these, the subject wrote at the experimenter's dictation the right letter or letters. In the

* *Right* in these cases means, of course, using *v* after *a*, *l* after *b*, *h* after *c*, etc.

last, he wrote any letter (or letters) other than the one (or more) dictated that made a real word. He was instructed as follows:

> You are now to write letters to complete the words on these pages. In each case you will first write three times the letter or letters that I tell you to write, and then you will write any other completion than the one I have had you write. For example, if the word is *tr.ck* and I say "a" you will write *track track track* and then *trick* or *truck*. If the word is *fla..* and I say "sk" you will write *flask flask flask* and then *flame* or *flash* or *flare* or *flail* or any other five-letter word beginning with *fla*. Do this as fast as you can without making mistakes.

Ten seconds were allowed for the subject to write the dictated letter three times and to think of and write some other letter to make a word. If he failed to do so, he was started on the next line.

As Table 98 shows, there was little or no influence of the 2880 writings of *v* after a seen *a*, *l* after a seen *b*, etc., in the direction of strengthening the tendency to think of and write *v* in the space after *a*, *l* in the space after *b*, etc., in the new words of the final test.*

When, therefore, we do obtain such a strengthening as a consequence of repetition plus reward, it seems probable that it is the reward that is accountable for the greater part of the strengthening.

* The five individuals who took the tests and training without any previous acquaintance with them showed no influence at all; and perhaps they give a better measure of the fact than all ten individuals together. The other five, who had had a short training (six runs of the series of 160 with announcements of *Right* and *Wrong* preceded and followed by a test of 40) four weeks earlier, were perhaps influenced by that. In the test before it they had 11, 14, 12, 11, and 15 correct and in the test after it, 16, 16, 8, 14, and 16. They thus gained 2.2 (P.E., ± 1.3). Ca, Da, DeB, So, and Wi took a similar training with announcements of *Right* and *Wrong* after the dictation experiment. They scored 10, 15, 8, 12, and 14 in the test before it and 7, 7, 13, 12, and 11 in the test after it, with an average of —1.8 (P.E., ± 1.3). We may then argue that the preceding training by dictation is deleterious to later training by reward while preceding training by reward is beneficial to later training by dictation. Or we may argue that a majority of one group reacted to both experiments in a way different from that of the majority of the other group.

TABLE 98

THE INFLUENCE OF REPEATEDLY COMPLETING 160 WORDS BY THE ADDITION OF *v* AFTER *a*, *l* AFTER *b*, ETC., UPON THE TENDENCY TO USE *v* AFTER *a*, *l* AFTER *b*, ETC., IN COMPLETING OTHER WORDS

	Individual	Number Right Before Training	Number Right After Training	Gain	
Individuals with no previous experience of the series	Ca	9	8	−1	
	Da	10	12	2	
	DeB	13	11	−2	
	So	14	11	−3	
	Wi	10	11	1	
Average				−0.6	P.E. ±0.6
Individuals who had previously been trained with 960 responses followed by *Right* or *Wrong* and tested again	L	16	18	2	
	McV	15	16	1	
	R	11	19	8	
	Si	11	13	2	
	St	13	19	6	
Average				3.8	P.E. ±0.9
Average for both groups				1.6	P.E. ±1.0

It is true that this repetition due to writing letters from dictation is not the same thing as the repetition of the self-initiated thinking and writing of a letter. But if 144 writings of *v* after *a* from dictation strengthen the tendency to do so by zero, we cannot well expect a large influence from a dozen self-initiated completions in Experiment 56. We are not able to devise a completion experiment absolutely like Experiment 56 save in the replacement of reward plus some repetition by repetition alone.

It is of some interest to observe whether the general frequency of certain letters in the dictated completions strengthens the tendency to use these letters in general in the final test.

The letters *o, i,* and *u* occurred oftenest in the training. They averaged 53 in the early test, and 55 in the late. The letters *r, t,* and *v* occurred next oftenest in the training. They averaged 40 in the early test, and 28 in the late. The letters *a, e, h, l,* and *n* occurred next oftenest in the training.

They averaged 23 in the early test and 29 in the late. The letters *b, c, d, f, g, j, k, m, p, q, s, w, x, y,* and *z* occurred least often in the training. They averaged 1.6 in the early test and 0.6 in the late. The six of greatest frequency in the training fell off from 244 in the early to 208 in the late test. The twenty of less frequency in the training gained from 139 to 154 in the tests. The facts in detail appear in Table 99.

The one clear result of the training with dictated completions was to strengthen the tendency to try *a, e,* and *o* oftener (176 in the late test to 112 in the early test). This may have been due to the satisfyingness of so doing. They are often easy means of completing the words. The letters *a* and *e* gain more than *o*, and much more than *i* and *u*.

TABLE 99

THE RELATION BETWEEN FREQUENCY IN THE DICTATED COMPLETIONS AND GAIN IN FREQUENCY FROM THE EARLY TO THE LATE TEST

		Occurrences		
	Training by Dictation	Initial Test	Final Test	Gain
o	28	45	72	
i	25	80	58	
u	22	35	35	
Av. *o, i, u*	25	53	55	2
t	16	27	25	
v	14	12	5	
r	12	45	23	
Av. *t, v, r*	14	28	18	–10
a	11	37	52	
l	10	14	12	
h	9	24	17	
n	8	10	12	
e	5	30	52	
Av. *a, l, h, n, e*	8.6	23	29	6
Av. for other fifteen letters	0	1.5	0.6	–0.9

Experiments with Four-Inch Lines

Cards were prepared, each with four lines four inches long or with imperceptible differences therefrom. There were 200 cards in all. Each card was identifiable in the following manner. Ten of them, when shown, were accompanied by the words *This is number 1, 11, 21, 51, 71, etc.* Ten of them were accompanied, when shown, by the words *Begin at the top of the column.* These cards were among the numbers 41, 51, 81, 91, etc. Twenty of them had the numbers 5, 10, 15, 20, 25, or the like, marked on them in the middle of the card. Twenty of them had such numbers marked on them at the right-hand end of the card. Twenty of them had one of the lines drawn two millimeters wider (i.e., thicker) than the others. Twenty of them had a slight thickening, as if by a mistake in drawing, somewhere in one of the lines or a small ink blot somewhere on the card. Nineteen of them had the right-hand end cut off 1½ inches shorter than the others so that the space from the end of the fourth line to the edge of the card was about ½ inch instead of 2 inches. Twenty of them had a 2-inch space at the left-hand side of the card and a 1-inch space at the right-hand end of the card beyond the black lines, whereas, in the cards in general, the reverse held true. Twenty of them had one line broken by two white crossbars. Twenty of them had one line broken by four white crossbars. Twenty-one of them were unaltered.

The two hundred cards were presented in two series: series *O* and series *X*. None of the subjects who were experimented with knew which series was being presented at any given time.

Experiment 58

The first experiment with these lines was designed to discover whether associations could be formed between the identifiable feature of a card and the judgment as to which of the four lines was the longest. The differences

in length, it will be remembered, were imperceptible, being substantially zero. The card was shown to the subject who recorded his judgment as 1, 2, 3, or 4, meaning that he thought that the first line at the left, the second, the third or the fourth line at the extreme right was the longest. The card would then be put out of sight, and the correct number would be announced as, "Two is right," "Three is right," etc. From 600 to 2400 cards were so exposed, 500 or 600 daily for four or five days.

The associations were formed in the case of most subjects. When they are formed they may be known by the subject in the usual sense of the term, i.e., the subject may be aware that a card accompanied by the words, "This is Number so-and-so," always has the fourth line as the longest; that a card which is cut by two white crossbars always has the second line as the longest; that a card with number 5 or 10 or 15, etc., on the card in the middle, always has the first line as the longest, and so on. Such cases are of no particular interest to our purpose, but in many cases the association is more or less formed without the subject's being to any extent thus aware of it. He increases his number of correct responses gradually but does not reach 100%, and under cross-examination reveals that he is unaware of the system of construction and identification of the cards. Some subjects are definitely aware of the associations for some of the cards, especially the cards accompanied by words or marked by numbers, but are entirely unaware in the case of a card which has 1½ inches cut from it, or which has disfigurement, or which is distinguished only by being regular, i.e., by having no alteration.

Having demonstrated that persons who have the right response told to them again and again in the course of presentations of these 200 cards often come to have a tendency, even without awareness of the constitution of the series in the case of any set of twenty cards, to connect the right response with the identifying characteristic of the cards, we are now in a position to study the influence of

repetition and of reward upon the formation of such associations. This is done by two new experiments, using in one case the same cards as were described above, and in the other case, two series of cards (*S* and *T*) which are similar except that the difference in length of the longer line is made more nearly perceptible. In the *S* and *T* series, each consisting of 100 cards, one line is made from 1½ mm. to 2½ mm. longer than the others. It is then perceived as longer in from 30 to 50 percent of the cases (44% on the average). There is, however, no great confidence and surety in the perception. The individual who has made judgments of the cards will have made the right judgment very much oftener than chance, but he will not have felt much, if any more, satisfaction at the right judgment than at the wrong. He will feel insecure about all of them. In the other experiment, the original *X* and *O* series of cards are shown; the individual judges them; after the judgment is made, the card is put away and he is told by the experimenter simply *Right* or *Wrong*. Since the cards used in this experiment are indistinguishable as to length, the subject gets in the beginning only 25 percent of the judgments right. Consequently repetition or frequency favors erroneous judgments to exactly the same extent as it favors correct judgments. If he comes to increase the correct judgments, it is because the announcement of *Right* or *Wrong* works back upon the associations to strengthen some and weaken others.

We have, then, a sharp contrast between a form of learning where repetition with very little effect is active and one where effect is active with no aid from repetition except such as the influence of the effect itself causes.

Experiment 59

Eight subjects were trained with the *S* and *T* series, where frequency favored the right responses, and eight with the *X* and *O* series with announcement of *Right* or *Wrong*. Both groups were tested before and after the

training with the X and O series with two series called *Modified* X and *Modified* O in which the positions of the X and O cards were shifted about and some cards were replaced, so that any associations possibly formed with position in the X or O series would be without favorable influence.

The facts for the group who had the action of frequency with little or no chance for effect to operate are shown in Table 100.

TABLE 100

THE INFLUENCE OF FREQUENCY ON THE CONNECTIONS BETWEEN FEATURES OF CARDS EACH SHOWING FOUR 4″ LINES AND THE CHOICE OF A LINE IN A CERTAIN POSITION AS THE LONGEST

Individual	Responses During the Training: Right	Responses During the Training: Wrong	Percent Right	Number Correct Out of 200: Before Training	Number Correct Out of 200: After Training	Gain	Percent Correct: Before Training	Percent Correct: After Training
26	635	878	42	50	56	6	25 0	28.0
27	716	796	47	32	36	4	16.0	18.0
28	464	621	43	53	50	−3	26.5	25.0
29	601	912	40	48	50	2	24.0	25.0
30	638	875	42	47	51	4	23.5	25.5
31	611	901	40	45	45	0	22.5	22.5
32	528	504	51	55	52	−3	27.5	26.0
33	748	764	49	41	43	2	20.5	21.5
Average				46.4	47.9		23.2	23.9

The training caused approximately 620 right responses per person to 760 wrong responses, or 260 for each of the three wrong responses, and caused the correct response to be made approximately 2.4 times as often as one of the three wrong responses.

The total number correct out of 1600 was 371 before the training and 383 after training. The average gain was 1.5 (or 3.2%) with a mean square error of 1.1. The influence of pure frequency is thus slight in the case and conceivably *nil*. The gain of 3.2% may conceivably be the result of the satisfyingness of the occasional instances where the subject felt sure that his judgment was right. These would occur

with the right number about 2¼ times as often as with any one wrong number.

The facts for the group who had announcements of *Right* or *Wrong* but no action of frequency save what was caused indirectly by the effects of the *Right* and *Wrong* are shown in Table 101.

TABLE 101

THE INFLUENCE OF SATISFYING AND ANNOYING AFTER-EFFECTS ON THE CONNECTIONS BETWEEN FEATURES OF CARDS EACH SHOWING FOUR 4″ LINES AND THE CHOICE OF A LINE IN A CERTAIN POSITION AS THE LONGEST

Individual	Responses During the Training Right	Responses During the Training Wrong	Percent Right	Number Correct Out of 200* Before Training	Number Correct Out of 200* After Training	Gain	Percent Correct Before Training	Percent Correct After Training
34	583	1597	27	43	40	−3	21.5	20.0
35	612	1188	34	45	51	6	25 0	28.3
36	533	1467	27	50	55	5	25.0	27.5
37	656	1600	29	43	58	15	21 5	29.0
38	649	1351	32	37	86	49	18 5	43 0
39	552	1448	28	58	45	−13	29 0	22 5
40	585	1485	28	37	51	14	20 6	28.3
41	545	1755	24	49	46	−3	24.5	23 0
Average				45.3	54 0		23 2	27 7

* Out of 180 for 35 and 40.

From Table 101 are omitted all the records where there is any evidence that the subject had learned that 1 (or 2 or 3 or 4) was always right for such and such a kind of card, including also all the records where he seemed to have learned that a number at the center was either 1 or 3 or that a card with a number at the right was either 1 or 3, or that *This is number* . . . meant a 3 or a 4, or that *Begin at the top of the column* meant a 3 or a 4, or that the first card with two white bars in any series was a 2, or the like. Table 101 thus gives us an estimate of the unconscious strengthening of the connections. The total number of rights in Table 101 increases from 362 before the training to 432 after the training with an average of 9 or 19.6 percent, contrasted with the 1½ or 3.2 percent for the group

influenced by much frequency and little effect. The average of 9 is, however, not very reliable, there being a variation among individuals from −13 to +49. The mean square error of the 9 is 6.4. The training included approximately 600 right responses per person to 500 for each of the wrong responses, so that the subjects in this group were at a disadvantage compared with those of the other in respect of the relative frequency of the right responses during the training. They had fewer rights and many more wrongs.

So far as it goes, then, this experiment supports the hypothesis that the connections between certain sorts of cards and the choice of the line in position 1, 2, 3, or 4 as the longest, were strengthened by the back-action of the *Right* and *Wrong* irrespective of any awareness by the subjects of any connection between sort of card and position of the longest line, and to an extent much beyond what the excess of frequencies of right responses over wrongs in the training itself can account for.

Experiment 60

A second experiment was performed as a check with eight new subjects, who were tested, trained with announcements of *Right* and *Wrong*, and then tested again. Two of them came to understand the construction of the cards in whole or in part. Their records are not used in what follows. There was some evidence that three other individuals had some ideas about certain of the cards, and their records are also omitted in so far as concerns these cards.* The facts for the others appear in Table 102. There is a change from an average percent correct of 23.7 to one of 33.8. This average gain of 10.1% (equivalent to 20.2 for the entire test of 200) is much larger than was the case for the other group. It has a mean square error of a little over 1.

Taking all fourteen individuals together, we have an

* *Blot, number at right,* and *number at center* for person 43; *This is number . . . , Begin at the top, number at right,* and *number at center* for person 44; *two white crossbars, four white crossbars, blot, This is number . . . ,* and *Begin at the top* for person 47.

average gain in percent correct of 7.1 with a mean square error of 2. The average gain in percent correct for the eight subjects aided by frequency alone was 0.8 with a mean square error of 0.5½. The difference of 6.3 in favor of the former has a mean square error of less than 2.1.

TABLE 102

SAME AS TABLE 101, BUT FOR INDIVIDUALS 42 TO 47

	Responses During the Training			Number Correct Out of 200 *			Percent Correct	
Individual	Right	Wrong	Percent Right	Before Training	After Training	Gain	Before Training	After Training
42	913	2087	30	47	61	14	23.5	30 5
43	608	1572	28	29	47	18	20 7	33 6
44	713	1527	32	32	49	17	22.9	35.0
45	871	2129	29	59	69	10	29 5	34.5
46	1054	2146	33	45	65	20	22 5	32.5
47	451	1049	30	28	44	16	23 3	36 7
Average				40	56		23.7	33.8

* Out of 140 for individuals 43 and 44; out of 120 for individual 47.

It is possible that some of the cards in the training series were recognized by some particular accidental feature of the numbers written on them, or by the blots made on them deliberately, or by spots of dirt, cracks or the like, and that some of these recognitions carried over to some cards of the modified *X* and *O* series used in the final tests.

It is very unlikely that Experiment 59 suffered from this, but Experiment 60, in which the training was much greater and concentrated within about two weeks, may have suffered. It would have been better to prepare an entirely different series for use in these tests, instead of simply changing the order and replacing some of the cards by new ones.

We have done this in Experiment 61, and also guarded further against the acquisition of knowledge of the construction of the series by continuing the experiment with interspersed tests and for only the time shown in the program below.

Experiment 61

Experiment 61 was like Experiment 60 except that all tests were made with a set of 100 cards, series Z, no one of which was ever seen except during the tests, and that the program for all subjects was as follows:

I. Test, 1-50 of series Z.
II. Training with announcement of *Right* or *Wrong*, 8 sets of 50 each, series O and X.
III. Test, 51-100 of series Z.
IV. Training as in II.
V. Test, 1-50 of series Z.
VI. Training as in II.
VII. Test, 51-100 of series Z.

At the close of the experiment, each individual supplied the facts called for by the following questions:

Did you, at any time during the experiment, have any ideas about the relation of any sort of card or line to the lengths of the lines? ....
If so, what ideas did you have? ....

Only those individuals are used as evidence whose replies show total ignorance of the construction of the series, and

TABLE 103

SAME AS TABLE 101, BUT FOR INDIVIDUALS 48 TO 56

Individual	Responses During the Training: Right	Responses During the Training: Wrong	Percent Right	Number Correct out of 50 in Tests: Before Training	Number Correct out of 50 in Tests: After Training	Gain	Percent Correct: Before Training	Percent Correct: After Training
48	346	854	29	13	13	0	26	26
49	303	897	25	11	18	7	22	36
50	342	858	29	12	17	5	24	34
51	399	801	33	20	21	1	40	42
52	425	775	35	12	19	7	24	38
53	375	825	31	13	14	1	26	28
54	331	869	28	8	15	7	16	30
55	369	831	31	13	15	2	26	30
56	411	789	34	11	17	6	22	34
Average	367	833	31	12.6	16.6	4	25.1	33.1

whose judgments give internal evidence to the same effect. Using their records, we have the facts of Table 103. These show that the results of Experiments 59 and 60 are little, if any, influenced by identifying particular cards and learning the correct responses for them and using this knowledge in the final tests. As a result of only 367 correct responses per person during the training, there is a gain in the percent correct in the tests from 25.1 to 33.1. This gain of 8 has a P.E. of ±4.

Experiment 62

A series of 40 cards, each with four lines on it, was made consisting of 8 cards on which the lines were red and the first line at the left was the shortest, 8 cards on which the lines were black and the second line from the left was shortest, 8 cards on which the lines were blue and the second line from the left was shortest, 8 cards on which the lines were printed near the edge of the card and the third line from the left was the shortest, and 8 cards on which the lines were cut by a crossbar and the line at the right was the shortest.

The differences in length were such that subjects got a little over 50% right at the beginning of the training. Six individuals were trained, one at a time, to judge which line was the shortest. Right or wrong was announced after each judgment. The cards were shuffled and presented in a new order each time. Two individuals began to get correct ideas about the constitution of the series in the second and fourth round and are not considered in what follows. Two individuals made no improvement in the course of 20 rounds or 160 judgments of each sort of card. The other two individuals, though they never became aware of the system of construction of the cards, improved as shown on the following page, presumably in whole or in part by a strengthening of the connections between redness and a tendency to say 1, etc., of which they were unaware.

Number of correct responses of M and St in order (out of 80).

M	48	52	50	50	54	45	55	48	56	69	67	64	
St	35	31	35	35	38	50	48	49	54	47	49	56	52
Sum	83	83	85	85	92	95	103	97	110	116	116	120	

We sought to devise instructive experiments on the influence of rewarding hidden connections which could be made with many individuals as a group. Experiments 63, 64, and 65 are the result, and would perhaps be useful if carried on for many hours, or arranged frankly as guessing contests. But as they were given, the subjects probably responded too exclusively to the comparative lengths of the four lines on each card.

Experiment 63

Series were arranged in which four sorts of cards (*blots, two cuts, mark at right,* and *regular*) were made with the longer lines all enough longer so that they were judged corrected in 48 to 50 percent of the trials, but not enough longer to permit certainty in any judgment; whereas, four other sorts (*mark at center, 1 1/2″ shorter, four cuts,* and *thicker**) were made with the longest line fairly clearly so in about one card in five, but with the lengths in the other cards differing only infinitesimally. When one of these cards on which the difference was made fairly clear was shown, it was judged correctly in about 80 percent of the trials, and after the subject had recorded his judgment the experimenter announced *1 is right* (or *2* or *3* or *4*, according to the sort of card). The total percent correct for this second group of four sorts of cards was 37.

We have then, within the trial series, four sorts of cards where the right connection is much more frequent than chance, but has a satisfying after-effect very rarely or never, and four sorts where the right connection is less frequent at the start, but has in about one case out of six the satisfying after-effect of inner certainty and corroboration by the announcement of . . . *is Right.*

* For the *thicker* cards in these series, line 4 was longest, not line 3 as in the experiments with four-inch lines hitherto described.

We can compare the gains during the training for these two sets of four cards each, and the gains in a test series in which the differences in length were infinitesimal for all cards.

Our first experiment of this sort used as the test series the hundred cards of the O series, and as training 114 cards which were displayed in many different orders, so that the subjects would not be tempted to use order in making their judgments.

TABLE 104

THE INFLUENCE UPON TWO GROUPS OF SATISFYING AFTER-EFFECTS COMPARED WITH THE INFLUENCE OF FREQUENCY IN THE CASE OF CONNECTIONS BETWEEN CERTAIN FEATURES OF CARDS AND JUDGMENTS THAT A LINE IN A CERTAIN POSITION IS THE LONGEST

	Group A n = 10	Group B n = 8
Cards Subject to Frequency		
Number of judgments of cards during training	301	374
Percentage correct during training	49	47
Percentage correct in the test before training	27	27
Percentage correct in the test after training	24	25
Gain of test after training over test before training	−3	−2
Cards Subject to Satisfying After-Effects		
Number of judgments of cards during training	289	361
Percentage correct during training	35	38
Percentage correct in the test before training	29	26
Percentage correct in the test after training	29	27
Gain of test after training over test before training	0	1

Two groups of ten and eight graduate students of education served as subjects. No individual had, during the experiment, any correct idea about the system of the cards or any feature thereof. The facts are shown in Table 104.

Experiment 64

An experiment identical with this except that the amount of practice was less (703 judgments, or an average of 88 for each kind of card) was performed with forty-nine subjects. Their answers to the questions below showed no

comprehension of any feature of the construction of the series.

Did you, at any time during the experiment, come to think that certain sorts of lines were regularly longer than others, or certain cards with certain features regularly had line 1 or 2 or 3 or 4 longest?

If so, what features of lines or cards did you thus associate with

A	1 being the longest	....
B	2 " " "	....
C	3 " " "	....
D	4 " " "	....

The frequency of correct judgments during the training estimated from 253 (taken at random from the 703) was 37% for the cards with occasional reward and 47% for the cards with frequency only.

In a test with thirty-two cards in which there were no differences in length made before and after the training, there was no gain in the percentage of correct judgments for the four which had had the frequency of 47%; and there was a loss for the four which had had the frequency of 37% plus an occasional reward. The number correct out of 784 was 138 before training and 136 after training for the former, and 161 before training and 138 after training for the latter. In percents, there are 17.6 to 17.3 and 20.4 to 17.6.

In a test with forty cards of the 114 used in the training, the only gain displayed was in the six cards for which correct judgments had been rewarded. These showed 66% of correct judgments instead of 56% as in their first trials. The fourteen cards of similar design but with little or no difference in the length of the lines and no rewards had 24% right early and late. The twenty cards with differences in length had 45% right early and 46% right late. The gain in the six cards was presumably due to association with special clues.

Experiment 65

A series was arranged after the general plan just described, but for a very short experiment. There were one

hundred cards in all. The first ten consisted of one each of the eight sorts of cards on all of which the four lines differed only imperceptibly, and of two cards of a new sort, each having one length 3 mm. longer than the others. The last ten were duplicates of the first ten. The four "new sort" cards are not used in any of the records that follow. The others comprised the initial and final test. The intermediate eighty cards comprised ten each of the eight sorts. *Blots, two cuts, mark at right,* and *regular* were made with the longer lines enough longer so that they were judged correctly in almost 50 percent of the trials, but not enough longer to permit certainty in any judgment. *Mark at center, 1 1/2″ shorter, four cuts,* and *thicker* were made with the longest line clearly longer in about one card out of five. There were nine cards which thus permitted correct judgments approximately 80 percent of the time. After the individuals had recorded their judgments of one of these cards, the experimenter announced . . . *is right.*

One hundred and nine individuals were tested with the series under the guise of an experiment in learning to discriminate lengths. No one of the 109 had any correct idea about the construction of the cards.

The four sorts of cards subject to repetition without any attachment of satisfyingness were judged correctly 2329 times out of the 4360, or 53%, during the training. The number correct in the tests fell off 21, from 135 to 114. The four sorts subject to occasional easy discriminations and announcements of . . . *is right,* were judged correctly 1578 times out of 4360, or 36%, during the training. The number correct in the tests fell off 9, from 105 to 96. The ratio of 2329 to 1578, or 148 to 100 shown in respect of the frequency of right judgments would be only slightly altered by more extended experiments. The 148 has a mean square error of only 1½. The difference of 12 in favor of the connections which were occasionally followed by satisfyingness might be much altered in more extensive experiments of the same sort. It has a mean square error of 14.

We repeated the experiment with eighty-seven other persons. In their case we have not counted the number of correct and incorrect responses during the training. It may be assumed to be over 50% for the four sorts of cards subject to frequency and under 40% for the cards subject to occasional easy discriminations and announcements of *Right*. The number of correct responses fell off for both in the test. The drop was 12 for the "frequency" cards (from 84 to 72). It was 20 for the "satisfying" cards (from 94 to 74).

Combining the results for the 196 individuals, we have practically no difference between the cards judged correctly often but with little satisfyingness and those judged correctly less often but with more satisfyingness. The drop is 33 in the former (from 219 to 186) and 31 in the latter (from 199 to 168), neither being reliable.

Taken together, Experiments 63, 64, and 65 show practically zero influence of both repetition and reward upon the "hidden" connections. It seems probable that in such short series, in which also many of the cards do have one line perceptibly different in length from the others, the subjects are not led into the comfortable habit of taking a quick impressionistic look at the card and guessing. They continue throughout the experiment to scrutinize the lengths. Consequently, they do not form connections with any features of the cards save relative lengths of the lines.

Experiment 66

A series of 73 slips of paper was constructed, all of the same width but of varying lengths as shown below.

Six individuals were trained with this series in the following manner: A slip was shown; they estimated its length to the nearest quarter-inch; the slip was withdrawn from view and the experimenter announced *Right* or *Wrong*. The slips were shown in four different orders.

Two of the six individuals (R and Sp) did not improve, and we have no further concern with them here.

Constitition of the Training Series of Lengths: Number of Occurrences of Each Length

3	2	5	2	7	4	9	1	11	1
3.25	2	5.25	1	7.25	8	9.25	4	11.25	4
3.5	2	5.5	2	7.5	2	9.5	1	11.5	1
3.75	2	5.75	1	7 75	4	9.75	1	11.75	1
4	2	6	1	8	2	10	2	12	1
4.25	4	6.25	4	8 25	1	10.25	1		
4.5	1	6.5	1	8.5	2	10.5	1		
4.75	1	6.75	1	8.75	1	10.75	1		

In the case of the other four, we find the number of right judgments out of 73 rising from ½, 3, 3½, and 0 in the first two trials of the series to 6½, 11, 22, and 25 in trials 13 and 14, and to 15½, 18, 23, and 22½ in trials 15 and 16. We have as averages for successive pairs of trials 1.8, 9.1, 11.8, 15.5, 15.1, 19.8, 16.1, and 19.8. These records show that the after-effects in the shape of *Right* and *Wrong* strengthened the connections between the sights of certain shapes and the correct estimates of their lengths. Our present concern is, however, with the existence of a subtler effect. Will the rewarding of, say, *Seven one* (the verbal form used for an estimate of seven and one-fourth inches) cause a strengthening of the tendency to say *Seven one* as a response to any length under the conditions of the experiment?

We record the number of times that each response from four up was given by each individual in the first twelve trials of the series of 73 lengths, and the number of times it was rewarded by *Right.** We then divide all these responses of each individual into three groups approximately equal in the number of responses, but differing in the number of *Rights*. For example, in the case of individual M the three groups (which we shall designate as RR, R, and L, meaning much reward, reward, and least reward) were:

* Responses of *three three, three two, three one,* and *three* and still shorter lengths are not used because these are soon so easily estimated by vision alone that subtler general tendencies would not be expected to play any considerable part. Using them would simply dilute our data.

RR four three, five, six one, seven one, nine, nine one, ten, ten one, ten two, eleven, and eleven three, used in all 260 times, of which 65, or 25%, were rewarded.

R four, six, seven two, eight one, eight two, and twelve, used in all 244 times, of which 24, or 10%, were rewarded.

L four one, four two, five one, five two, five three, six two, six three, seven, seven three, eight, eight three, nine two, nine three, eleven, eleven two, twelve one, twelve two, twelve three, and thirteen, used in all 277 times, of which 5, or 2%, were rewarded.

RR, R, and L for the other three subjects were constituted in a similar way by selecting the responses most rewarded, those least rewarded, and those left as an intermediate group; and we have for M, N, P, and Ro the facts shown in Table 105.

TABLE 105

THE FREQUENCY, FREQUENCY OF REWARD, AND PERCENT REWARDED OF THE RESPONSES OF TRIALS 1 TO 12, EXCLUDING LENGTHS UNDER 4″

n = number of responses r = number rewarded %r = 100 r/n

	RR			R			L		
	n	r	%r	n	r	%r	n	r	%r
M	260	65	25	244	24	10	277	5	2
N	257	65	25	247	21	8½	251	3	1
P	251	80	32	271	40	15	256	10	4
Ro	246	96	39	226	38	17	298	27	9
All	1014	306	30	988	123	12½	1082	45	4

We then examine the records to determine whether the connections leading to RR responses gain in strength more than the equally frequent but less often rewarded L responses. We may measure the change in strength by the change from trials 1 and 2 (or from trials 1, 2, 3, and 4) to trials 13 and 14 (or 13, 14, 15, and 16, or 15 and 16, or 17, 18, 19, and 20).

Table 106 presents the facts.* By whatever comparison

* The change from trials 1, 2, 3, 4 to trials 17, 18, 19, and 20 is not exactly comparable to that using trials 13, 14, 15, and 16. By the end of trial 16, the status as to frequencies and percents rewarded has changed from that

we make, the rewarded connections gain more in strength that the equally frequent connections with less reward, even after all the specific gains in the connections attaching certain responses to certain lengths are omitted from consideration. If we average the balances due to reward for the 1, 2 to 13, 14 and 1, 2 to 15, 16 comparisons for each individual and then compute the average for an individual, this is .12 ± .04 (P.E.). If we use the 1, 2, 3, 4 to 13, 14, 15, 16 comparisons, the comparable numbers are .10½ ± .026 (P.E.).

TABLE 106

CHANGES IN THE STRENGTH OF CONNECTIONS OF GROUPS RR, R, AND L, OPERATING WITH EQUAL FREQUENCIES BUT DIFFERING AMOUNTS OF REWARDS

	RR/RR+R+L			R/RR+R+L			L/RR+R+L			
	A Trials 1,2	B Trials 13,14	B–A	C Trials 1,2	D Trials 13,14	D–C	E Trials 1,2	F Trials 13,14	F–E	RR–L Balance
M	.287	.309	022	.235	.400	.165	.478	.291	−.187	.209
N	.276	.364	.088	.339	.282	−.057	.386	.355	−.031	.119
P	.231	.358	.127	.306	.326	.020	.463	.316	−.147	.274
Ro	.368	.312	−.056	.295	.269	−.026	.337	.419	.082	−.138
All	.286	.336	.050	.295	.321	.028	.419	.343	−.076	.126
	1,2	15,16		1,2	15,16		1,2	15,16		
M	.287	.293	.006	.235	.384	.149	.478	.323	−.155	.161
N	.276	.490	.214	.339	.250	−.089	.386	.260	−.126	.340
P	.231	.316	.085	.306	.237	−.069	.463	.447	−.016	.101
Ro	.368	.337	−.031	.295	.270	−.025	.337	.393	.056	−.087
All	.286	.349	.063	.295	.277	−.018	.419	.374	−.045	.108
	1 4	13–16		1–4	13–16		1–4	13–16		
M	.262	.283	.021	.267	.410	.143	.471	.307	−.164	.185
N	.283	.357	.074	.373	.310	−.063	.343	.333	−.010	.084
P	.260	.335	.075	.364	.325	−.039	.376	.340	−.036	.111
Ro	.335	.357	.022	.330	.254	−.076	.335	.389	.054	−.032
All	.284	.332	.048	.334	.327	−.007	.382	.341	-.041	.089
	1–4	17–20		1–4	17–20		1–4	17–20		
M	.262	.288	.026	.267	.410	.143	.471	.302	−.169	.195
N	.283	.356	.073	.373	.341	−.032	.343	.303	−.040	.113
P	.260	.359	.099	.364	.205	−.159	.376	.436	.060	.159
Ro	.335	.389	.054	.330	.238	−.092	.335	.374	.039	.093
All	.284	.342	.058	.334	.302	−.032	.382	.355	−.027	.085

shown in Table 106 to the following: RR, 1420 occurrences, 31% rewarded; R, 1307 occurrences, 14% rewarded; L, 1391 occurrences, 6% rewarded. The RR group is thus now at a slight advantage over L in number of occurrences. However, the balance of change in favor of RR from trials 1, 2, 3, 4, to trials 17, 18, 19, 20 should properly be reckoned for a new RR and a new L constituted on the basis of trials 1 to 16 instead of 1 to 12. It would then probably be somewhat greater than that shown in Table 106.

The differences cannot be accounted for by any conscious favoring of the rewarded responses. The subjects knew very little about which responses they favored, and were not apparently helped at all by what they thought they knew up through trial 16. The training was continued to 30, 42, 38, and 21 trials of the series for M, N, P, and Ro, respectively, and followed by a certain test. The subjects then answered the following questions:

1. In the training with the quarter-inch slips, did you come to think that any lengths occurred oftener than others? ....
2. If so, which lengths were they? ....

M answered "Yes; 6½, 7, and 7½," which had frequencies in the series of 1, 4, and 2. If we omit her responses of *six two, seven* and *seven two* from the computations, the balance in favor of the rewarded would be much greater. She used 6½ and 7 very often, but almost never had them rewarded. N answered "Yes; 7¼." If we omit his responses of *seven one*, the balance in favor of the rewarded would be reduced only slightly, since it was not until about trial 20 that he began to use 7¼ much more frequently than *seven* or *seven two* or *seven three.* P answered "Yes; 11¼." If we omit her responses of *eleven one*, the balance in favor of the rewarded would be reduced only very very slightly. Ro answered "Yes; 3." Three occurred only twice in the series, and three is already omitted from our computations. The total result of omitting these possible cases of thinking *"7 1/4 has been right rather often; I will try 7 1/4"* and the like would be to make the balance in favor of the rewarded responses a little greater.

There are only two possible explanations of a balance in favor of the rewarded, frequency being equal. One is that which has been put forward here, that the satisfying after-effect strengthens not only the specific connection between the specific lengths and *seven one, nine one,* etc., but also the connection between *any strip as shown under the general conditions of the experiment* and *seven one.* If *six*

three has a weak connection of this general sort, and *seven one* a strong one, a strip really seven inches long will be called *seven one* oftener than *six three*—and that is what happens. The other is that the subjects, though they were prevented by the plan of the experiment from repeating or rehearsing these connections with *any strip* specifically, were permitted to repeat them by holding in mind some image of the strip and the response to it, discarding them upon hearing *Wrong*, but retaining them in connection (or reinstating them) as long as possible upon hearing *Right*. *Seven one* would thus be connected to that imagined strip, and also to the general situation of *any strip in this experiment* longer than some other response equally frequent but less often rewarded. The learning to use *seven one* oftener erroneously would be due to learning to use it successfully; and both would be due to retaining certain connections longer, or reinstating them. One connection would be between an imaged length and *seven one*; the other, between some imaginal or other ideational equivalent of the general feature, *any strip displayed as in this experiment,* and *seven one.*

What is needed to decide this issue in such experiments is knowledge of how often and for how long such continuation or reinstatement of the rewarded connections takes place. Then we can balance rewarded connections against non-rewarded, with the latter occurring enough oftener to make their occurrences equal the actual plus the ideational repetitions of the rewarded. It is hard to secure this knowledge.

So far as this particular kind of experiment is concerned, the second explanation is possible. As a general principle, it encounters almost insurmountable difficulties. Some of these have been shown already in the case of the multiple-choice learning of word meanings; others will appear in later experiments comparing the influence of rewards and punishments; still others appear in the learning of games of skill, such as tennis and billiards, where there

is often no chance to retain or reinstate a rewarded connection, because the player is immediately busy with something else; still others appear in the learning of dogs, cats, rats and the like who can hardly be supposed to interrupt their nibbles in the food box by reviews and rehearsals of how they got there.

Experiment 67

This experiment was like Experiment 66 except that the training series consisted of 80 slips ranging from 2½ inches to 12 inches by steps of ½ inch, and favored the fractional lengths and the lengths 4, 4½, 8 and 8½ inches. Its constitution was as follows:*

L	F	L	F	L	F	L	F
2½	4	5	2	7½	4	10	2
3	2	5½	4	8	7	10½	4
3½	4	6	2	8½	7	11	2
4	7	6½	4	9	2	11½	4
4½	7	7	2	9½	4	12	2

* L = length, F = frequency.

The purpose of the experiment was the same as in the case of Experiment 66. Four subjects, Ch, Dr, L, and O, were trained with announcements of *Right* and *Wrong*. All improved. We record the number of times that each response from *six two* up to *twelve two* was given by each individual in the first eight trials of the series, and the number of times it was rewarded by *Right*. We then form RR, R, and L groups for each individual, as in Experiment 66. The results appear in Table 107.

We measure the change in strength for RR, R, and L responses by the change from trials 1 and 2 to trials 9 and 10. The results appear in Table 108. The average balance in favor of the RR group compared with the L group is .19 ± .05 (P.E.).

One of the subjects (L) may possibly have consciously favored estimates of 8 and 8½ by the time trials 9 and 10 were reached. Her judgments of *eight* and *eight two* num-

TABLE 107

THE FREQUENCY, FREQUENCY OF REWARD, AND PERCENT REWARDED OF THE RESPONSES OF TRIALS 1 TO 8, FROM 6½″ TO 12½″

n = number of responses. r = number rewarded. %r = 100 r/n.

	RR			R			L		
	n	r	%r	n	r	%r	n	r	%r
Ch	125	58	46	127	54	42½	98	17	17
Dr	117	52	44½	130	27	21	100	13	13
L	112	64	57	125	57	45½	115	33	29
O	129	76	59	123	57	46	145	38	26
All	483	250	52	505	195	38½	458	101	22

TABLE 108

CHANGES IN THE STRENGTH OF CONNECTIONS OF GROUPS RR, R, AND L OPERATING WITH EQUAL FREQUENCIES, BUT DIFFERING AMOUNTS OF REWARD ½″ LINES

	RR/RR+R+L			R/RR+R+L			L/RR+R+L			RR–L
	A Trials 1,2	B Trials 9,10	B–A	C Trials 1,2	D Trials 9,10	D–C	E Trials 1,2	F Trials 9,10	F–E	Balance
Ch	.250	.339	.089	.417	.435	.018	.333	.226	–.107	.196
Dr	.152	.247	.095	.379	.532	.153	.470	.221	–.249	.344
L	.286	.314	.028	.304	.229	–.075	.411	.457	.046	–.018
O	.154	.333	.179	.354	.250	–.104	.492	.417	–.075	.254
										Av. = .19 ± .05 (P.E.)
All	.208	.305	.097	.367	.382	.005	.425	.313	–.112	.209

bered 34, 17, 31, 30, and 35 in successive sets of 160. After trial 14, she reported: "*Yes; 4, 4 1/2, 8, 8 1/2,*" to the following questions:

1a. When you were learning to estimate the lengths of the white strips of paper, did any lengths seem to you to occur especially often?........ b. If so, which lengths were they?.............

No other subject gave any indications of having noticed the frequent occurrence of 8 and 8½, and no subject of the four noted the greater frequency of the half-inch over the whole-inch lengths. If we omit the data of 8 and 8½ in the case of L, the balance in favor of the greater strengthening of the rewarded connections is slightly reduced. The L lines in Tables 107 and 108 would then read as follows:

Table 107. RR, 77, 42, 54½; R, 79, 30, 38; L, 84, 23, 27½
Table 108. .237, .190, –.047; .342, .333, –.009; .421, .476, .055; –.102

The totals for the tables would read as follows:

Table 107. 448, 228, 51; 459, 168, 36; 427, 91, 21
Table 108. .195, .293, .098; .378, .401, .023; .427, .306, –.121; .219

The average balance would be .17 ± .05½ (P.E.).

Experiment 68

Five subjects were trained in estimating the area in square inches of each of a series of 74 pieces of paper of varied shapes and of sizes ranging from 10 to 39 square inches, as shown below. They were permitted to inspect three squares of 10, 25, and 50 square inches as often as they wished during the training. *Right* and *Wrong* were announced after each judgment.

The sizes and frequencies of the 74 pieces of paper used in Experiment 68 were as follows:

Size	f	Size	f	Size	f	Size	f	Size	f	Size	f
10	2	15	1	20	6	25	6	30	2	35	9
11	1	16	3	21	4	26	1	31	7	36	1
12	1	17	1	22	3	27	1	32	1	37	1
13	1	18	1	23	1	28	6	33	1	38	1
14	1	19	3	24	4	29	2	34	1	39	1

One of the subjects (Sp) did not gain in the number of correct estimates, apparently being so exclusively devoted to estimating each by comparing them with the standards that he did not attach the rewards to the connections.

The others improved as follows: L, who had thirteen trials with the series, changed from 28 and 23 correct in the first two to 41 and 32 in the last two. M, who had twenty-nine trials, changed from 6 and 6 in the first two trials to 48 and 47 in the last two. P, who had twelve trials, changed from 18 and 29 to 31 and 30. St, who had twenty-eight trials, changed from 15 and 22 to 40 and 39. We are not here concerned with these measures, however, except as evidence that the particular rewarded responses to particular shapes did strengthen those particular connections. Our concern is the question whether the reward of, say, 28 as a response to certain particular shapes caused a strengthen-

ing of the tendency to say 28 as a response to any shape under the general conditions of the experiment.

We record the number of times that each number from 15 up was said by the subject in all trials of the series up to the last two, and the number of times that it was rewarded by *Right.** We also record the number of times that each number from 15 up was said in the first two trials and in the last two trials (or in trials 19 and 20 if the subject had more than 20 trials with the series), omitting, however, the cases where the response was *Right.*

We then measure the influence of reward, frequency being equalized, as follows for each subject: We list the numbers said according to the percentage of rights in trials up to the last two, and divide them into three groups, (1) a group beginning at the top of the list and going down to numbers with approximately 40% of right responses, (2) a group beginning at the bottom and going up until the total number of responses in trials up to the last two is approximately the same as the total number in group 1, and (3) a group of the numbers in the middle of the list, not used in (1) or (2). We then compute the change in the number of erroneous responses from trials 1 and 2 to trials next to last and last for each of the three groups of numbers just described. Our question is whether the reward attached to certain numbers will make the subject more likely to use them at the end than at the beginning in his erroneous responses.† We may call these three groups RR, L, and R, respectively.

For example, individual P's record, given in Table 109, shows that the RR's, with 201 occurrences, of which 121

* The reason for not using numbers below 15 square inches is that these small areas may be estimated too readily.

† The reason for not using the correct responses in trials 1 and 2 and in trials next to last and last is that these may be used more at the end than at the beginning because they have been specifically rewarded in connection with that particular piece of paper. We are here concerned with a general strengthening of the tendency to use the numbers apart from the learning of the sizes of certain particular pieces of paper.

were rewarded, showed a gain from early to late trials of 7 (15 to 22), whereas the L's, with 195 occurrences, of which 8 were rewarded, showed a loss from early to late trials of 19 (42 to 23). The R's were intermediate.

We also may divide the R group among the RR and L groups so as to have all the numbers 15 or above which the subject used included in one or the other group. In the case of P, we would transfer 25 and 22 to the RR group making its totals 143, 116, 26, and 31 and transfer 19, 21, 26, 27, 33,

TABLE 109

SAMPLE OF DATA AND COMPUTATIONS USED IN OBTAINING THE MEASUREMENTS OF TABLE 110. INDIVIDUAL P

Number	Times Used up to the Last Two Trials of the Series: Rewarded	Times Used up to the Last Two Trials of the Series: Not Rewarded	Times Used in Wrong Responses: In Trials 1 and 2	Times Used in Wrong Responses: In Trials Last and Next to Last	Grouping	Data Rearranged by Groups RR, R, and L					
15	1	11	2	1	L	RR	16	24	11	1	4
16	24	11	1	4	RR		20	36	18	4	4
17	1	6	1	1	L		24	16	21	3	6
18	2	10	1		L		28	13	15	0	4
19	2	7	3		R		35	28	12	5	4
20	36	18	4	4	RR		39	4	3	2	0
21	4	9	2	2	R		Total	121	80	15	22
22	10	20	4	5	R						
23	1	21	4	3	L	R	19	2	7	3	0
24	16	21	3	6	RR		21	4	9	2	2
25	12	16	7	4	R		22	10	20	4	5
26	3	9	3	2	R		25	12	16	7	4
27	3	18	5	4	R		26	3	9	3	2
28	13	15		4	RR		27	3	18	5	4
29		12	4		L		33	4	11	3	7
30	2	34	8	4	L		36	2	10	4	4
31	1	10	2	2	L		Total	40	100	31	28
32		38	8	5	L						
33	4	11	3	7	R	L	15	1	11	2	1
34		10	4	1	L		17	1	6	1	1
35	28	12	5	4	RR		18	2	10	1	0
36	2	10	4	4	R		23	1	21	4	3
37		9	3	1	L		29	0	12	4	0
38		10	2		L		30	2	34	8	4
39	4	3	2		RR		31	1	10	2	2
40		5	1	3	L		32	0	38	8	5
41					L		34	0	10	4	1
42		4	1		L		37	0	9	3	1
43		2		1	L		38	0	10	2	0
44		2			L		40	0	5	1	3
45		2			L		42	0	4	1	0
46				1	L		43	0	2	0	1
47							44	0	2	0	0
48		1	1		L		45	0	2	0	0
							46	0	0	0	1
							48	0	1	1	0
							Total	8	187	42	23

and 36 to the L group making its totals 26, 251, 62, and 42. Let us call the two groups of "more rewarded" and "less rewarded" thus formed MR and LR. The MR group then has 259 occurrences and shows an increase of 5 in the number of its numbers used as wrong responses. The LR group has 277 occurrences and shows a corresponding decrease of 20.

The results for individuals L, M, P, S, and St by both sorts of computation are shown in Table 110. The more-rewarded numbers did surpass the less-rewarded numbers in the strengthening of their connections with the general situation of estimating areas in the experiment, their per-

Table 110

The tendency to use increasingly, in estimating areas, numbers which have been rewarded

Individual	Group of Numbers	Frequency	% Rewarded	Occurrences as Wrong Responses: In 1,2	Occurrences as Wrong Responses: In Last and Next to Last	% Gain	RR/RR+L: A In 1,2	RR/RR+L: B In Last and Next to Last	B–A
L	RR	293	65	29	40	38	.39	.59	.20
	R								
	L	279	17	46	28	−39			
M	RR	97	51	8	5	−38	.40	.50	.10
	R	908	15	91	65	−29			
	L	97	0	12	5	−58			
P	RR	201	60	15	22	47	.26	.49	.23
	R	140	29	31	28	−10			
	L	195	4	42	23	−45			
St	RR	508	54	42	23	−45	.42	.30	−.12
	R								
	L	537	15	58	53	− 9			
							MR/MR+ML		
L	MR	293	65	29	40	38	.39	.59	.20
	LR	279	17	46	28	−39			
M	MR	522	30	45	33	−27	.41	.44	−.03
	LR	580	6	66	42	−36			
P	MR	259	45	26	31	19	.30	.42	.12
	LR	277	9	62	42	−32			
St	MR	508	54	42	23	−45	.42	.30	−.12
	LR	537	15	58	53	− 9			
Sums	RR	1099		94	90	− 4			
	R	1048		122	93	−24			
	L	1108		158	109	−31			
	MR	1582		142	127	−11			
	LR	1673		232	165	−29			
MR/MR+LR				.38	.43½				
LR/MR+LR				.62	.56½				

centage rising from .38 in the first two trials to .43½ in the last two. This rise of .05½ is, however, extremely unreliable, and two of the individuals show the reverse tendency. (The differences for the individuals corresponding to the .05½ for the sums are .20, —.10, .12, and —.12, giving Av. .02½, with a mean square error of ±.07.)

A larger average difference probably should not be expected (I should in fact expect one smaller), but the argument that it is due to the influence of the reward would be much stronger if all individuals showed it in about the same degree. Three out of four do show the difference in that direction if RR/RR+L is measured for early and late trials, and the average difference is then larger (.10), as it should be if reward has the effect in question.

The records of individual Sp show in Group RR numbers said 329 times, 55% of which were rewarded. Even when all the other numbers said by the subject are put in L, their occurrences are only 230. Of these 8% were rewarded. The RR numbers occurred as wrong responses 41 times in the first two trials and 34 times in the last two. Corresponding records for the L numbers are 54 and 41. RR/RR+L thus is .43 for the early trials and .45 for the late. The inclusion of Sp would thus make little or no difference to our general results.*

Experiment 69

Before and after from 10 to 32 repetitions of the series of 74 areas in Experiment 68, the five subjects (L, M, P, Sp, and St) were tested in estimating the area in square inches of each of a hundred or more pieces of paper of varied shapes and of sizes ranging from 10 to 44 square inches, chosen from a set of several hundred such. They had before them constantly the three standard squares of 10, 25, and 50 square inches, and could inspect them at will.

* There is a possibility that P thought that 22 square inches occurred especially often among the sizes, and that St thought that 22 and 25 square inches did. If 22 is omitted in the case of P, the result is practically unchanged. If 22 and 25 are not used in the case of St, the result is slightly more favorable to the influence of the reward.

Our question here is whether the frequency of responses 16, 19, 20, 21, 22, 24, 25, 28, 31, and 35 and the more frequent attachment of *Right* to them in the training series will strengthen the tendency to respond by 16, 19, 20, 21, etc., rather than by 17, 18, 23, 26, 27, etc., in the test series, and will do this without any awareness on the part of the subjects that certain areas were more frequent in the training series. If this is the case, we can plan other experiments to measure separately the potency of frequency and of the *Right, Wrong* effects.

The answers of the five subjects to the relevant questions were as shown below.

Questions:

1. When you were learning to estimate the areas of the pieces of paper and cardboard, did any sizes seem to occur especially often?
2. If so, which sizes were they?
3. Did you consciously favor these sizes in the test at the end of the training?

Answers:

L	1. No	2.	3. No
M	1. No	2.	3. No
P	1. Yes	2. 22	3. No
Sp	1. No	2.	3. No
St	1. Yes	2. 22 and 25	3. Yes

We therefore omit St from our calculations and shall keep a separate record of P as regards judgments of 22.

Even if we admit all the data from P, there is only very weak evidence that the greater frequency and more frequent rightness of 16, 19, 20, 21, etc., in the training strengthened the tendency to respond by these numbers in the test series. Their occurrences rise only from 128 to 139, two subjects showing an increase and two a decrease. The average increase of 2.8 has a mean square error of 3.3. There is no demonstrable difference between those four subjects and a group of control subjects who took the same tests but lacked the training.

Experiment 70

Because of these results from this experiment, we planned an experiment where the training would favor certain sizes even more, using as a training series a hundred pieces of paper in which there were five occurrences each of 21, 31, 41, 22, 32, 42, 24, 34, 44, 16, 26, 36, 18, 28, 38, 19, 29, and 39, and only one each of 17, 20, 23, 25, 27, 30, 33, 35, 27, and 40. Also, assurance of a high percentage of rights in the training for the favored sizes were obtained by the following arrangements. The 21, 31, and 41 pieces were all rectangles; the 22, 32, and 42 pieces were all rectangles plus a triangle on top; the 24, 34, and 44 pieces were all rectangles with the upper right-hand corner cut off; the 16, 26, and 36 pieces were all rectangles with a triangular piece cut out from the top; the 18, 28, and 38 pieces were all triangles; and the 19, 29, and 39 pieces were all fairly simple long, narrow pieces. These changes were too successful, six of the eight subjects coming to understand the system almost completely and one in part. Consequently there could be no surety that the strengthening of tendencies to favor sizes ending in 1, 2, 4, 6, 8, and 9 in the test series was not deliberate.

We may, however, observe the changes that occur in the training series itself before any awareness of any part of the system of its construction appears. The appropriate observations are of two sorts. First we may record the number of correct responses in the first four rounds of judgments of the hundred surfaces, omitting any variety in which the number correct rises above 33 1/3% (5 out of 15) at or before the fourth round, and all responses for any subject in whom this happens for more than one variety.

These omissions include all the records of one subject and the records with the triangles of two subjects who had 3, 4, 5, and 9 and 0, 2, 6, and 10 right out of 15 in the first four rounds. For the rest we have, as the successive totals, 37, 48, 50, and 59, clearly showing gradual learning.

Next, we may compare the frequency of erroneous responses ending in 1, 2, 4, 6, 8, or 9 in the first and the fifth round for these seven subjects, to determine whether the attachment of the satisfying *Right* to these endings strengthened the tendency to use them apart from any particular shape whose sizes may have been learned. The percent rises for the different subjects from 61 to 72, 40 to 56, 66 to 94, 44 to 72, 44 to 48, 61 to 63, 69 to 84.

The rise from 66 to 94 is the only one in relation to which there is ground for suspicion that the subject deliberately avoided responses ending in 0, 3, 5, or 7. All these responses still occurred (except those ending in 0 and 3 for that one subject) but with diminishing frequency. So the most probable explanation is that the tendency to think of a number ending in 1, 2, 4, 6, 8, or 9 waxed and the tendency to think of a number ending in 0, 3, 5, or 7 waned because the former had been so much oftener followed by the satisfying *Right*.

That this learning was largely due to the formation of connections between the six general features of 90 of the 100 shapes rather than to the formation of connections with particular shapes is indicated by the fact that, out of a total of 194 rights, 110 were single occurrences for a given shape for a given individual, 46 were due to 23 shapes estimated correctly twice, 30 were due to 10 shapes estimated correctly three times, and 8 to 2 shapes estimated correctly four times. The same tendency is indicated further by the fact that all the gain comes in the rectangles, rectangles cut in, and triangles. They change from 13 to 21 to 23 to 34 correct, whereas the other three shapes show 24, 27, 27, and 25 correct. Of the thirteen of the former shapes estimated correctly in the first round, eight were never estimated correctly again in round 2, 3, and 4; one was estimated correctly again in round 2, another in round 3, and another in round 4; only two were estimated correctly in all four rounds. Of the gain of 8 from round 1 to round 2, only 3 could possibly be accounted for by special connections. Of

the 23 of these shapes in round 3, 15 had not been estimated correctly in either of the earlier rounds, and 13 were not estimated correctly in the fourth. Of the 34 of these shapes estimated correctly in the fourth round, only 10 had been estimated correctly in the third round.

Apparently the connection between, say, *a large triangle* and saying *28* is strengthened by its after-effects, at first without any awareness by the subject. Later the subject becomes aware that he is calling *a large triangle 28* with very frequent success and decides to do so uniformly.

Before and after the training with the series of 100 areas, the eight subjects were tested with a series of 190 areas of which 50 were rectangles, rectangles with a corner cut off, triangles and other shapes like the six chiefly used in the training, while 32 were somewhat like them, and 108 were queer shapes, like none in the series of 100 except, in some cases, the 10 queer shapes which it contained.

There is a tendency in the late test to increase the number of responses with numbers ending in 1, 2, 4, 6, 8, and 9 at the expense of those ending in 0, 3, 5, and 7, even in the case of these 108 queer shapes. This is what would be expected as a result of the satisfying after-effects of responding by 1, 2, 4, 6, 8, and 9 as end digits, but it is not a proof and probably is not evidence of such influence. It could have happened as a consequence of a decrease in the tendency to estimate coarsely in multiples of 5, regardless of how that tendency was brought about. Responses with 3 or 7 as end digits in fact gain in terms of percentages more than responses with 1, 2, 4, 6, 8, or 9 as end digit (78 to 118 compared with 496 to 612, or by 51% compared to 23%). So the most reasonable explanation is simply that estimates in multiples of 5 were replaced by estimates on a finer scale.

Evidence from Experiments 33 to 38 of Chapter IV

We may seek evidence concerning the existence of a tendency of satisfying consequences of a connection to strengthen it in the following manner. In the experiments

with series of word-number pairs or number-number pairs, correct anticipation of the second member of a pair is, as a rule, satisfying. If, for example, in the *angel* series one hears *act*, thinks *10*, and finds this to be correct, one is satisfied. If the satisfyingness strengthens not only the connection between *act* and *10*, but also, to some slight degree, the connection between *thinking of a number for a word in this experiment* and *thinking of 10*, there will be a tendency to think of a number which one has associated with a certain first term not only when that first term is presented, but when any first term is presented. Since numbers which are given as correct responses in the test are very often numbers which have been correctly anticipated before the test, we can discover whether this general effect of satisfyingness exists by observing whether the numbers given as correct responses in the test appear among the wrong responses oftener than numbers occurring with equal frequency in the series, but not given as correct responses.*

Such a spreading effect of the satisfyingness of thinking *10* for *act* from *act*⟶*10* to *any word in the series*⟶*10*, if it existed, would be presumably very slight. It might be zero, although the satisfyingness of thinking *10* for *act* had real potency on *act*⟶*10*. Fortunately, we have an abundance of material so that we can determine even a slight difference between numbers occurring in right responses and numbers of equal frequency in the series not so occurring.

In the series *Number Number* 3856 with the eight subjects of June, 1928, we used numbers appearing as correct responses two or more times. The number of times (A) that such numbers were given by the individual in question as wrong responses and (B) that numbers of equal (or slightly

* Except for such a general effect of satisfyingness we should expect that numbers appearing in the correct responses would appear a little less often in the wrong responses than other numbers of equal frequency in the series. For example, knowing or thinking that *10* was right for *act*, and that many different numbers were used in the series, an individual would tend to guess some number other than 10 for other words.

greater) frequency were so given were as shown below. The numbers favored by satisfyingness occur in general two and a half times as often.

Individual	A	B	Ratio A/B
Be	20	19	1.1
Br	5	3	1.7
Gr	28	$8^1/_3$	3.4
H	9	3	3.0
L	4	$1^2/_3$	2.4
Rob	11	3	3.7
Rot	1	1	1.0
S	15	4	3.8
Median			2.7
Average			2.5 ± .7 (P.E.)

If we use numbers appearing once as a correct response, the corresponding facts are:

Individual	A	B	Ratio A/B
Be	43	18	2.4
Br	28	25	1.1
Gr	45	28	1.6
H	37	45	0.8
L	43	33	1.3
Rob	26	31	0.8
Rot	31	26	1.2
S	42	17	2.5
Median			1.25
Average			1.5 ± .4 (P.E.)

In the case of the group of 162 individuals who were tested after hearing the *bacon* series, we have replies to these questions: (1) "Did you think that certain numbers occurred especially often in the series? (2) If so, which numbers were they? (3) Did you favor these numbers in the test, or (4) Did you simply write the first number that came into your mind for each word?" We use only individuals who answered the first or third question negatively. We shall report the facts for sixty individuals taken in groups of ten each at random.

For example, the Bell group of ten showed thirteen numbers given correctly twice or more. These appeared 26

times in the wrong responses. Thirteen numbers of approximately equal frequency in the series appeared 18 times in the wrong responses. Using the numbers given correctly once in the test by an individual, we have the following counts of appearances among the wrong responses, for them (A) and for other numbers occurring equally often in the series (B).

Individual	A	B	Ratio A/B
Be	14	6 5	2.2
Br	33	9 5	3 5
Bro	9	6.5	1.4
Cr	24	15.0	1.6
Ea	19	9.0	2.1
Er	17	4.0	4.3
F	7	4.0	1.8
Fr	10	5.5	1.8
H	11	4.0	2.8
W	16	14.5	1.1

The median ratio is 2.0.

The Chen group of ten had as comparable figures 42 and 15 for cases of two or more occurrences as right responses, and the following for the numbers given correctly once (A) and the control numbers (B).

Individual	A	B	Ratio A/B
H	8	9.5	0.8
Ho	31	14.5	2.1
Sh	5	6.5	0.8
St	46	3.5	13.1
V	33	35.0	0.9
Ch	22	9.5	2.3
Cr	13	9.5	1.4
Gr	10	8.5	1.2
Ha	10	12.0	0.8
Hu	19	12.5	1.5

The median ratio is 1.3.

The Alston group of ten had 13 and 10 for cases of two or more occurrences as right responses and the following for numbers given correctly once:

Individual	A	B	Ratio A/B
Al	8	8	1.0
Be	23	8	2.9
Bi	7	3	2.3
Bl	9	6	1.5
Cl	14	10	1.4
De	23	16	1.4
Di	17	20	0.9
Ev	26	9	2.9
S	15	18.5	0.8
Sm	3	3	1.0

The median ratio is 1.4.

Similar treatment for three other random tens gives median A/B ratios of 1.3, 1.65, and 1.75.

The sixty individuals as a whole showed 219 appearances among the wrongs of numbers given correctly twice or more. Numbers of equal frequency in the series appeared 104 times in the wrong responses. The ratio is thus 2.1.

Using the numbers given correctly once in the test by an individual, and obtaining for each individual an A/B ratio like those shown above, we find for all sixty the facts shown in Table 111. The median ratio is 1.5. The medians for six random groups of ten each are 2.0, 1.3, 1.4, 1.3, 1.65, and 1.75. The average of these six is 1.6 ± .07 (P.E.)

The eight college students who were subjects in the *bacon* experiment had already undergone a similar experiment. Whether this made them likely to be more or less satisfied by correct anticipatory responses I do not know.

Cases of two or more occurrences of a number as a correct response which had a number of equal frequency in the series not given as a correct response to use in comparison are scanty, so I combine them for all subjects. Numbers occurring correctly three or more times occurred as wrong responses 1.8 times as often as their control numbers. Numbers occurring correctly twice occurred as wrong responses 2.3 times as often as their control numbers. For numbers given correctly once, the eight subjects showed ratios of 6.6, 1.5, 1.4, 1.7, 1.8, 2.0, 1.6, and 0.9, the median being 1.65.

TABLE 111

FREQUENCIES AMONG SIXTY INDIVIDUALS (*bacon* SERIES) OF VARIOUS MAGNITUDES OF THE A/B RATIO

A equals the Number of Appearances in the Wrong Responses of Numbers Given by the Individual as Correct Responses. *B* equals the Number of Appearances in the Wrong Responses of Numbers Occurring Equally Often in the Series, but Not Given by the Individual as Correct Responses.

Ratio	Frequency	Frequency As a Percent
.4 or .5	1	1.7
.6 " .7	0	
.8 " .9	8	13.3
1.0 " 1.1	7	11.7
1.2 " 1.3	6	10.0
1.4 " 1.5	9	15.0
1.6 " 1.7	5	8.3
1.8 " 1.9	3	5.0
2.0 " 2.1	5	8.3
2.2 " 2.3	5	8.3
2.4 " 2.5	1	1.7
2.6 " 2.7	0	
2.8 " 2.9	4	6.7
3.0 " 3.1	1	1.7
3.2 " 3.3	0	
3.4 " 3.5	1	1.7

Also one each of 4.3, 4.8, 9.0 and 13.1, 1.7 percent each.

In the case of the thirteen individuals who had the *angel* series in March, 1928, I did not include the meaningful pairs with three occurrences each in the count of correct responses. Otherwise the treatment is the same as has just been described. One number was given correctly three times by one individual. Twenty-two numbers were given correctly twice. For these 23 numbers there were 29 appearances among the wrong responses. For 23 numbers of equal frequency in the series there were 17½ appearances. Using the numbers given correctly once by an individual, we have the following counts of appearances among the wrong responses, for them and for other numbers occurring equally often in the series, the median ratio being 1.4.

Similar computations for the eight college students of psychology gave a median A/B ratio of 1.15.

Individual	A	B	Ratio A/B
Ch	19	12.5	1.5
Cr	6	2.5	2.4
D	14	8	1.8
Dr	6	6	1.0
F	4	0.5	8.0
H	28	20.5	1.4
Hu	0	2	0
O	10	4	2.5
P	8	10	.8
R	8	4.5	1.8
Ro	2	6	.3
S	0	1	0
L	13	8.5	1.5

In the case of the *adopt* series, the number of occurrences was approximately the same for all the numbers. So here we compare the average frequency as a wrong response of the numbers given as correct responses with the average frequency as a wrong response of all the other numbers from 10 to 99. Since the cases of the same number being given correctly for two different words are very rare, we will include them with the cases where a number is given once as a correct response. For example, individual 82 had 13 right twice and 16, 22, 30, 40, 44, 60, and 93 right once each. These eight numbers occurred as incorrect responses 12 times, or an average of 1.50. The other 82 numbers occurred as wrong response 79 times (there being 100 words in the test), or an average of 0.96. The ratio is then 1.6.

The median A/B ratio for the fifty with the fewest correct was 1.2. The median for the half with the most correct was 1.0. The median for the entire group was 1.1, the distribution being as shown in Table 112.

For the inattentive hundred, the ratios have a median at exactly 1.0, those for the fifty with the fewest correct having a median of .9, and those for the fifty with the most correct having a median of 1.05.

In the *Number Number* experiment the eight college students had a median A/B ratio of 1.25.

If these facts are due to a general strengthening of the connections between the task of writing a number for any

Table 112

Frequencies of various magnitudes of the A/B ratio in the experiment with the *adopt* series

A/B	Frequency as a Percent Attentive Group	Inattentive Group	All
.0	0	1	0.5
.1	0	1	0.5
.2	1	2	1.5
.3	1	1	1.0
.4	4	2	3.0
.5	4	10	7.0
.6	6	11	8.5
.7	4	5	4 5
.8	8	4	6.0
.9	10	7	8.5
1.0	9	10	9.5
1.1	7	7	7.0
1.2	6	1	3 5
1.3	5	7	6.0
1.4	6	3	4.5
1.5	2	3	2.5
1.6	3	4	3.5
1.7	2	2	2.0
1.8	3	4	3.5
1.9	3	0	1.5
2.0	1	1	1.0
2.1	3	0	1.5
2.2	2	2	2.0
2.3	0	4	2.0
2.4	2	3	2.5
2.5–2.9	2	2	2.0
3.0–3.4	5	1	3.0
	and 1% at 7.9	and 1% at 3.7 and 1% at 4.4	and 0.5% each at 3.7 4.4 and 7.9

word in the experiment and thinking of numbers which have been *Rights* for some words, similar facts should be found after a lapse of time. And this is true so far as our experiments go. The eight college students who had heard the *bacon* series were tested again six days later, nothing having been said about the possibility of any such memory test. Using the numbers which had been right in the initial test, but counting their appearances in the memory test, the median A/B ratio is 1.3. These students were retested with

the *angel* series about ten days after the first test.* The median A/B ratio was 1.4. The corresponding A/B ratios for the first tests were 1.65 and 1.15, respectively, averaging 1.4.

We have evidence that these results are not due to deliberate favoring of numbers in general because they were right for certain particular words, aside from the testimony of the sixty summer-school students. The eight college students of psychology had five records each, so that we have five A/B ratios for each of them. If, now, some of them deliberately favored numbers in general because they were right for particular words, these individuals should show specially high ratios and show them rather consistently. They do not. As Table 113 shows, no individual had all five ratios above unity, and no individual had a median of the five A/B ratios that was more different from the median of the group than might well be explained by the general unreliability of the data and individual variations in the satisfyingness of correct anticipatory judgments.

There is not a shred of indication in the form of bimodality or otherwise that deliberate favoring caused the results.

TABLE 113

THE A/B RATIO IN EACH OF EIGHT INDIVIDUALS IN EACH OF FIVE EXPERIMENTS

	Subjects							
Test	Be	Bi	Gr	H	L	R	Ro	S
angel	.3	.6	1.1	1.4	4.5	1.0	1.2	1.3
" memory	1.0	1.7	1.1	2 0	3.1	1.0	.9	2.7
bacon	6.6	1.5	1.4	1.7	1.8	2.0	1.6	.9
" memory	3.0	5.9	.6	2 4	.6	1.4	.6	1.2
Number Number	2.4	1.1	1.6	.8	1.3	.8	1.2	2.5
Median	2.4	1.5	1.1	1.7	1.8	1.0	1.2	1.3

We have thus very strong independent evidence of the tendency of satisfying consequences of a connection to strengthen it. The median A/B ratios for the various groups are 1.25, 1.4, 1.65, 1.6, 1.15, 1.3, 1.4, 1.2, 1.0, .9, and

* I regret that the interval cannot be stated exactly, because of the loss of certain records. It was between 7 and 14 days.

1.05. There can be no question that the A/B ratio is above unity.

On the whole, the results of Experiments 49 to 68 and the other facts presented in this chapter prove that a satisfying after-effect of a connection can and generally does strengthen that connection directly, irrespective of repetitions or rehearsals or recalls of the connection and of images or other representations of the after-effect.

Evidence leading to the same conclusion appears in the learning of many skills where the learners do not, when confronted by a situation recall the previous response or set up any imaginal equivalent of its after-effect. A tennis player is confronted time after time by the situation of the ball coming from a certain quarter, in a certain direction, at a certain rate. His responses to it, as his training progresses, include fewer runs toward it that do not get to it, or that bring him to a poor position, and more that get him to it in a position enabling him to hit it well. But he does not as a rule, when confronted by that situation, think how he ran on the occasions when he got to it so as to make a good return, or imagine his act, how he hit the ball, his pleasure at doing so, or anything else about the connection or its consequences. As a rule he cannot do so, for *there is not time enough*. Similarly, a piano player who is improving preserves the movements which at any given point in the piece produce the tone and timing which satisfy her and her teacher, to the exclusion of those which produce a harsh or crude or inaccurate performance at that point. But she does not, as a rule, before reaching that point think of what she did previously that brought success, or of the success which is brought. As a rule, she cannot do so, for she lacks the time. In general, where a skilled act occurs as a part of a game or performance in which the response to one situation creates another that must be responded to *instanter*, there is not time, after a connection is made, to repeat it in fact or in imagination, and not time, when that situation recurs later, to recall the connection or its consequences.

Further evidence appears in much of the learning of babies and the lower animals. Even the most extreme advocates of representative thinking in infants, cats, dogs, rats, and the like would be reluctant to suppose that, for example, a cat improves its skill in catching birds by selecting the kind of leap which has associated with it a representation of capturing or eating the bird. A dog may occasionally choose path *A* rather than path *B* because the sight or smell of *A* calls up some representation of a satisfying sequent of doing so in the past, but very few animal psychologists will tolerate the requirement that a dog's learnings concerning where to go are at every choice caused by representations of outcomes. In general, in the lower animals, satisfying outcomes seem to exert their influence directly when they occur rather than indirectly through images of themselves later.

Certain very simple facts in human and animal behavior have a significance for theories of learning which nobody seems to have realized. These are the cases where the satisfying and annoying consequences of a connection strengthen and weaken it (or weaken it relatively by strengthening some other connection) *for the time being.* This happens where a certain situation or feature of a situation persists or recurs again and again at very short intervals. For example, let a young kitten that has never had any experience with fish or meat of any kind be confronted with a row of small flakes of cooked fish identifiable by shape, color, and smell. It will examine and eat one flake. Another piece is before it, and it repeats the examination (probably abbreviated) and the eating. And so on, so long as it is hungry, with abbreviation of the examination and full retention of the eating. The same kitten confronted in the same way by a row of small friable capsules covered with meat juice but containing weak acid will not strengthen the corresponding connection. Similarly a dog continues gnawing a bone and discontinues gnawing an object which gives him an electric shock. Similarly we continue to look peace-

fully at the grass or sky and discontinue looking at a glaring light.

Human and animal behavior shows millions of such cases of modification of response to a continuing or very soon repeated situation or feature of a situation. If the activity of a connection brings satisfaction, its activity is then and there continued or repeated.

In such cases of modification for the time being, the influence of the satisfying or annoying consequences seems indubitably direct. "It is fantastic to suppose that the satisfying taste does not in some direct manner validate and confirm the connection which persists or so soon recurs and that the annoying irritation does not directly reject and weaken the connection which is so soon abandoned. Would any students of animal behavior assume that the dog recalled an image of the electric shock and therefore avoided the object? Would any of you testify that you ceased looking at the glaring light because of any image of glare?

"Yet, the only difference between the influence of consequences on the connections in such cases and their influence in the stock experiments with animal and human learning is that in the latter the time interval between the successive repetitions of the situation is increased. If the kitten, having been satisfied by taking the first bit of fish, has a stronger tendency to take such a bit of fish a second later (say 20 percent stronger), the tendency would have been, say, 18 or 19 percent stronger if the second bit had appeared only after five seconds, and perhaps 15 or 16 percent stronger if the second bit had appeared only after two minutes. Nothing essentially different should be expected if the interval is two hours. If the strengthening or weakening of the neural bond which is the effective cause of learning occurs in the one case when the satisfier or annoyer occurs, not when we think about it afterward, it must in the latter also. The neurones have no means of telling whether the situation is to persist, or to disappear and recur hours later." [Thorndike, '31 pp. 61 f.]

It appears then that those who deny the direct and inevitable power of a satisfying after-effect to strengthen a tendency permanently so as to produce permanent learning ought to deny it any power whatsoever. If the consequences of a tendency cause the animal at the time to have that tendency more strongly or to displace it by some other tendency, these consequences will, as a rule, do so for the future as well.*

This argument is so important that I repeat it in brief. If there are satisfiers—states of affairs which the animal does nothing to abandon or avoid, after doing such things as attain and retain them—and if they act directly upon the connection which they follow and to which they belong so that the animal will at the time be more likely to continue or repeat the connection, if conditions permit, then, if conditions do not permit, as in maze-tracing, puzzle-boxes, multiple-choice experiments, most games and skills, and other cases where the situation does not recur till later, the animal will be more likely to repeat the connection when it does recur. The action is equally direct in both cases. The force of the satisfier in both cases is exerted when it occurs. If ideas of the satisfier are revived later in association with the situation, as they often are, the power which these ideas have is something other than the power which the satisfier had when it occurred.

I venture to suggest also that it seems highly unreasonable to give the imaginal representation of a satisfier power to strengthen a connection but deny that power to the satisfier itself.

Why have psychologists been so reluctant to believe that the satisfying after-effect of a connection strengthens it, and on the other hand often so ready to believe that an idea of such can do so? I think the reluctance is due to the unwillingness to believe that something which comes after a

* The exception would be the case of an animal which, so to speak, had learning but no memory, whose connections were capable of only temporary modifications and incapable of cumulative permanent results. The modifiability of some of the lower invertebrates may perhaps be of this sort.

connection can change it. Action by the idea of a satisfier is less repugnant because the idea comes ahead of the connection at its later occurrences.

The writer was perhaps the first to emphasize this difficulty in time relations ['98, pp. 103 f.], and has no desire to evade or minimize it. But surely it is not insuperable. The connection is a living thing in a living brain, and has just brought about and belongs with the after-effect. Anything that happens to it before or during its activity probably exerts its influence not mechanically as a lightning flash or blow would, but by relatively slow physiological processes. A second or two may not be of great importance.

We may consider the difficulty of the time relations profitably as follows: Assume that a satisfying state of affairs must strengthen *some* connection so that the question is simply how it comes so often to go back and strengthen the particular connection which produced it. What other connection would be a better candidate than this, to which the satisfier belongs?

Would the connection which immediately follows the satisfier? For example, we have in our multiple-choice experiments: *Inspection of a line⟶choice of word 2, announcement of Right. Inspection of the next line⟶choice of word 4, announcement of Wrong.* Should the satisfying *Right* strengthen more the choice in the following line? On the contrary, much less; for it does not sufficiently belong with it. Should it strengthen more the connections which follow it still more closely and are in part contemporaneous with it, namely, the connection between underlining the word in the first line and preparing to inspect the second, and the connection between hearing *Right* and preparing to inspect the second line? Some such strengthening there may be, and often is. Connections which are not intrinsically productive of the satisfier may yet be strengthened by it if they belong to it sufficiently. A person will very probably be readier to inspect the next line because of success with the previous. But the chief deciding factor is

belongingness. The connection *inspection of line 1* $\longrightarrow$ *choice of word 2* seems almost to wait until it has had its after-effect attached to it. We may well believe that, just as an impression leaves a brief so-called memory image for an appreciable time after the sensory excitation ceases, so a connection may leave what we may call an "after-connection" to last for an appreciable time after the actual choice of the word is made. At any rate, we are well aware what connection the satisfyingness chiefly belongs to, and something in the brain corresponds to that awareness; and somehow the satisfyingness does act upon it. We shall return to this problem after we have investigated the action of annoying after-effects in Chapter XI, and some possible explanations of the Law of Effect in Chapter XII.

CHAPTER XI

The Influence of Rewards and Punishments

In the early statements of the Law of Effect, the influence of satisfying consequences of a connection in the way of strengthening it was paralleled by the influence of annoying consequences in the way of weakening it.* As was stated near the beginning of the previous chapter, I now consider that there is no such complete and exact parallelism.

In particular, the strengthening of a connection by satisfying consequences seems, in view of our experiments and of certain general considerations, to be more universal, inevitable, and direct† than the weakening of a connection by annoying consequences. The latter seems more specialized, contingent upon what the annoyer in question makes the animal do, and indirect. For example, if an animal in a certain situation pulls a loop and gets food, or freedom, or praise, or any consequence then satisfying to it, the connection is likely to be strengthened (if it is modifiable at all) every time. But if an animal in the same situation pulls a loop and either (a) gets a shock in its paw at contact

* An early statement by the writer was as follows: "The Law of Effect is that: Of several responses made to the same situation, those which are accompanied or closely followed by satisfaction to the animal will, other things being equal, be more firmly connected with the situation, so that when it recurs, they will be more likely to recur; those which are accompanied or closely followed by discomfort to the animal will, other things being equal, have their connections with that situation weakened, so that, when it recurs, they will be less likely to occur. The greater the satisfaction or discomfort, the greater the strengthening or weakening of the bond. . . . By a satisfying state of affairs is meant one which the animal does nothing to avoid, often doing such things as attain and preserve it. By a discomforting or annoying state of affairs is meant one which the animal commonly avoids and abandons." ['11, pp. 244, 245.]

† How universal, inevitable, and direct the influence of satisfying after-effects is we shall consider later.

with the loop, or (b) gets a blow on the back, or (c) gets a sudden pain in the bowels, the weakening of the connections is likely to vary. In (a) there will probably be much weakening by way of the strengthening of the connection between the situation and the response of drawing back from the loop. In (b) there will probably be weakening, but less, because the reaction will probably be jumping away from the place, which is not so inconsistent with pulling at the loop. If the animal in (c) reacts by screaming without letting go of the loop, there may be no weakening at all.

The contrast may be put in another way, as follows: Rewards and punishments alike will teach by virtue of the conditions and activities which they produce in the animal. Rewards in general tend to maintain and strengthen any connection which leads to them. Punishments often but not always tend to shift from it to something else, and their educative value depends on what this something else is. They weaken the connection which produced them, when they do weaken it, by strengthening some competing connection.

It is the purpose of this chapter to present the facts which have led to these conclusions and, in particular, to demonstrate the existence of cases where punishment does not weaken the connection leading to it at all—does not strengthen the tendency to any other connection than that in the slightest degree.

Ordinarily, in the interplay of rewards and punishments we cannot tell to what extent the reward strengthens and to what extent the punishment weakens connections X_1, X_2, X_3, X_4, etc. The learning may be due to either alone or to both in various combinations. In multiple-choice learning, however, a suitable technique will enable us to decide whether C comes to prevail because it has been made stronger, and so displaces X_1, X_2, X_3, etc., or because X_1, X_2, X_3, etc., have been made weaker and so have left the field free for C. What this technique is will be clear from the accounts of its operation which follow.

*Experiment 71**

Nine subjects were given training in choosing the right meaning for a Spanish word from five in a series of two hundred lines like the five shown below. At each trial the subject chose a word and underlined it. If it was right the experimenter "rewarded" him by the announcement of *Right*. If it was wrong, the experimenter "punished" him by the announcement of *Wrong*.

1.	abedul	ameer....birch....couch....carry....punch
2.	abrasar	oaf....walk....fill....alienate....burn
3.	aceite	oil....copper....acerbity....crab....ferment
4.	acometer	calculate....asteroid....escort....attack....credit
5.	adefesio	defenceless....relief....nonsense....support....obstruct

The series was repeated each week-day (with some exceptions and with occasional double series on the later days), until there had been twelve or more repetitions of it.

We take, on the one hand, all the cases where the response was right in the second trial but not in the first, and, on the other hand, all the cases where the response was wrong in the second trial but was not that same wrong response in the first.† We compute how often in the former the next response is right, and how often in the latter the next response is any save that particular wrong. We subtract

* Some of the experiments designated Experiment 71, Experiment 72, etc., are experiments already described under other numbers, the difference being in the parts of the data that are used or the ways in which they are used.

The following list shows the relations:

Experiment 71 = 51
" 72 = 49
" 73 = 55
Experiments 74, 75, and 76 are new
Experiment 77 = 68
" 78 = 56
" 79 is new
" 80 = 45

† The reason for not using cases where the same response had occurred in trial 1 as in trial 2 is that we wish to exclude from the experiment all records with words whose meanings were known to the subject by reason of experiences prior to the experiment, and all records with words that may have had specially strong connections with some one response, right or wrong.

TABLE 114

THE INFLUENCE OF ANNOUNCEMENTS OF *Right* AFTER EACH RIGHT RESPONSE AND OF *Wrong* AFTER EACH WRONG RESPONSE

Experiment 71. The numbers 1, 2, 3, 4, 5, 6, 7, 8, and 9 refer to the individual subjects.

	1	2	3	4	5	6	7	8	9	Av.
Number of cases where a right response in the second trial, but not before, was followed in the next trial										
(*a*) by a right response	6	10	8	9	28	15	20	7	9	
(*b*) by a wrong response	8	31	19	15	24	12	16	15	21	
Percent which (*a*) is of (*a*+*b*)	43	24	30	38	54	56	56	32	30	
Percent due to chance	20	20	20	20	20	20	20	20	20	
Strengthening due to one connecting in trial 2 followed by *Right*	.23	.04	.10	.18	.34	.36	.36	.12	.10	.20
Number of cases where a wrong response in the second trial, but not before, was followed in the next trial										
(*c*) by any other response than it	62	93	76	70	60	54	89	106	87	
(*d*) by the same wrong response	24	23	22	30	33	26	20	20	30	
Percent which (*c*) is of (*c*+*d*)	72	80	78	70	65	68	82	84	74	
Percent due to chance	80	80	80	80	80	80	80	80	80	
Weakening of that response (or strengthening of responses other than it) due to one connecting in trial 2 followed by *wrong*	−.08	0	−.02	−.10	−.15	−.12	.02	.04	−.06	−.05

20% from the former and 80% from the latter to free the measures from the responses of the sort specified which mere chance would produce. These computations are shown in Table 114. The *Right* produces a substantial difference from what chance would give. The *Wrong* does not.

In a similar way we compare the influence of a response which was right in trial 3 and had not occurred before with that of a response which was wrong in trial 3 but had not occurred before. We do likewise using the responses of trial 4. The comparisons are shown in Table 115. The averages for all nine subjects using all the records of Tables 114 and 115 are 46, or 26 strengthening, for a right and 77, or —3 weakening, for a wrong.

Experiments 72 and 73

Two similar experiments, but using five meanings for each of 400 rare English words (200 in one experiment and 200 in another), as shown in the sample below, were conducted and treated in a similar manner.

16. desition	crossing....situation....ending....craving....legal paper
17. dowlas	bowie....fabric....grief....Indian soldier....howls
18. edacious	daring....tractable....sober....devouring....polite
19. eidolon	laziness....benefice....gift....duck....phantom
20. ern	long ago....foretaste....zeal....merit....eagle

The results appear in Table 116. Here again the *Right* produces a substantial strengthening, but the *Wrong* does not raise the frequency of responses other than that particular wrong above what chance would give. On the contrary, the six percents are all a little below 80. There are two possible explanations of their failure to reach at least the expectation by chance. One is that the wrong responses made early in the experiment (though not in the first trial) represent somewhat stronger tendencies than those not made then, and so have a probability of occurring stronger than one in five. A comparison of results for the influence of a *Wrong* in trials 2, 3, and 4 gives no support for this view. We had already got rid of any wrong tendencies of

TABLE 115

THE INFLUENCE OF ANNOUNCEMENTS OF *Right* AFTER EACH RIGHT RESPONSE AND OF *Wrong* AFTER EACH WRONG RESPONSE

Experiment 71. The numbers 1, 2, 3, 4, 5, 6, 7, 8, and 9 refer to individual subjects. The 3 4, 3 4, 3 4, etc., refer to data from the 3rd and 4th trials, respectively.

	1		2		3		4		5		6		7		8		9		Av.
Number of cases where a right response in the 3rd or 4th trial, but not before, was followed in the next trial	3	4	3	4	3	4	3	4	3	4	3	4	3	4	3	4	3	4	
(*a*) by a right response	4	7	5	4	10	9	14	9	26	14	3	6	15	15	7	8	6	9	
(*b*) by a wrong response	11	1	17	9	10	10	11	16	4	7	9	3	11	6	17	11	16	8	
Percent which (*a*) is of (*a*+*b*)	27	88	23	31	50	47	56	36	87	67	25	67	58	71	29	42	27	53	
Percent due to chance	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	
Strengthening due to one connecting in trial 3 or 4 followed by *Right*	.07	.68	.03	.11	.30	.27	.36	.16	.67	.47	.05	.47	.38	.51	.09	.22	.07	.33	.29
Number of cases where a wrong response in the 3rd or 4th trial, but not before, was followed in the next trial																			
(*c*) by any other response than it	39	29	79	67	59	49	51	49	38	32	43	23	56	46	91	65	49	47	
(*d*) by the same wrong response	16	15	22	9	20	14	12	11	20	13	15	9	18	7	18	19	14	8	
Percent which (*c*) is of (*c*+*d*)	71	66	78	88	75	78	81	82	66	71	74	72	76	87	83	77	78	85	
Percent due to chance	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	
Weakening due to one connecting in trial 3 or 4, followed by *Wrong*	−.09	−.14	−.02	.08	−.05	−.02	.01	.02	−.14	.09	−.06	−.08	−.04	.07	.03	−.03	−.02	.05	−.03

TABLE 116

THE INFLUENCE OF ANNOUNCEMENTS OF *Right* AFTER EACH RIGHT RESPONSE AND OF *Wrong* AFTER EACH WRONG RESPONSE
EXPERIMENTS 72 AND 73

	Experiment 72 (9 Subjects)				Experiment 73 (8 Subjects)			
	In 2nd	In 3rd	In 4th	Av.	In 2nd	In 3rd	In 4th	Av.
Number of cases where a right response in the 2nd or 3rd or 4th trial, but not before, was followed in the next trial								
(*a*) by a right response	148	79	80		121	133	72	
(*b*) by a wrong response	64	61	46		95	72	51	
Percent which (*a*) is of (*a*+*b*)	70	56	63		56	65	59	
Percent due to chance	20	20	20		20	20	20	
Strengthening due to one connecting in trial 2 or 3 or 4 followed by *Right*	.50	.36	.43	.48	.36	.45	.39	.40
Number of cases where a wrong response in the 2nd or 3rd or 4th trial, but not before, was followed in the next trial								
(*c*) by any other response than it	387	240	239		654	338	280	
(*d*) by the same wrong response	155	122	88		151	135	86	
Percent which (*c*) is of (*c*+*d*)	71	66	73		81	71	76	
Percent due to chance	80	80	80		80	80	80	
Weakening due to one connecting in trial 2 or 3 or 4 followed by *Wrong*	−.09	−.14	−.07	−.10	+.01	−.09	−.04	−.04

especial strength by using none which were made in the first trial. The other is that a wrong connection gains more strength by occurring than it loses by being declared wrong. This seems to be the fact.

It is conceivable, though hardly possible, that, in spite of the nature of the task and of our precaution of never using a response which occurred in the first trial, we may, by using responses which occurred somewhere from the second to the fifth trial, be favoring tendencies which have a strength over .20. Such a selective error would be important. If, for example, the real strength of the tendencies was .30, all our measures of strengthening of the rights in Experiments 71, 72, and 73 should be reduced by .10, and all our measures of the strengthening of responses other than the one wrong in question should be increased by .10, since they would be differences from .70, not .80.

To check against this we have measured separately the strengthenings in question due to *Rights* and *Wrongs* in trials 2, 3, 4, and 5, and in 2 and 3, 3 and 4, and 4 and 5. If responses used by us occurring in trials 2, 3, 4, and 5 represent stronger tendencies for the individual learners in question than .20, then the responses in trial 2 should represent stronger tendencies than those in trials 3, 4, and 5, the responses in trial 3 should represent stronger tendencies than those in 4 and 5, and so on (in all cases referring to the responses used by us).

Using the differences between trial 4 and trial 3 and trial 2 in Experiments 71, 72, and 73, we have an average of .0275 and .00, respectively, for *Rights,* and .05 and —.043 for *Wrongs*. The average of these averages is .01, with a mean square error of .017. In the case of Experiments 72 and 73 we have computed also the strengthening due to a response in trial 1 but not in trial A (the preliminary test without any announcement of *Right* or *Wrong*). Using the difference between the strengthening due to trial 2 and this we have .02 for *Rights* and .02 for *Wrongs.* Using the difference between the strengthening by occurrences in trials 3

and 4 and that by occurrences in trials 2 and 3 we have for Experiments 71, 72, and 73 .00 for *Rights* and —.027 for *Wrongs*. It is obvious that there is no considerable correction to be made in our results. We have .01 and .02 and —.014 as the difference between one trial and the next by the three independent determinations. We may safely assume as we have done that the strength of these responses to unknown words used by us was, apart from learning, very close to .20. The net result is trifling and, if used at all, must be used to make our estimates of the strengthening by a *Right* a trifle higher, and of the strengthening of other than a wrong by a *Wrong* a trifle more negative.

In Experiments 74, 75, and 76, next to be described, the situations could have had, apart from training, no tendency to evoke one of the ten responses rather than another, so that a probability of .10 for any one and of .90 for any other than that one may and must be used as the bases from which to measure strengthening.

Experiments 74, 75, and 76

In Experiments 71, 72, and 73, the interval between one trial and the next was usually a day, and 199 similar tasks intervened. In Experiments 74, 75, and 76, to be discussed now, the interval was only a minute or two and, on the average, only nine similar tasks intervened. In Experiment 74, the subjects were first familiarized with ten acts by doing them repeatedly at command. The acts were:

1 blink
2 reach hand forward
3 draw hand back
4 open mouth wide
5 turn head to right
6 turn head to left
7 put head forward
8 pull head back
9 scratch forehead with right hand
10 scratch right shoulder with left hand

The subjects were then instructed to learn which act belonged with each of ten cards by responding with one act as soon as a card appeared. The ten cards were as shown in Figure 6.

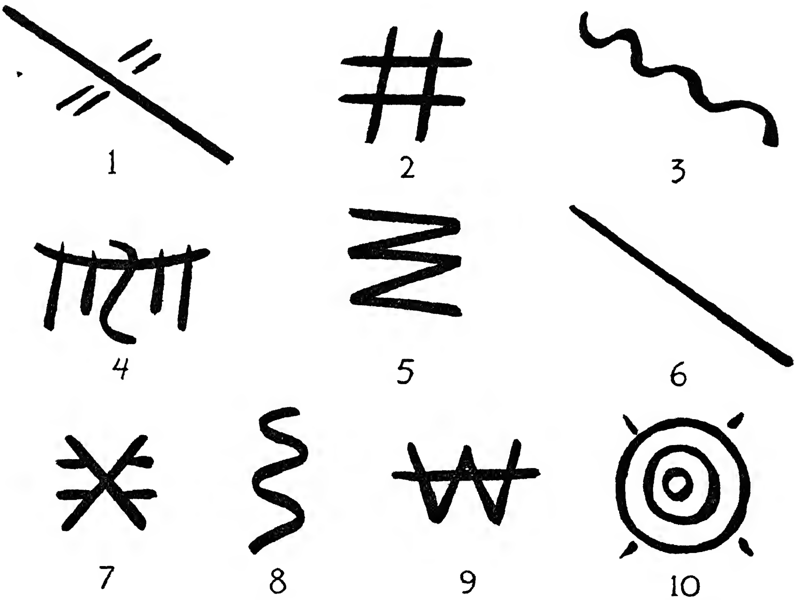

FIGURE 6. The ten cards associated with the ten acts of Experiment 74.

A series of 20, containing two trials (I and II) of each situation, was given without any announcement of *Right* or *Wrong*. We call these trials I and II. Then followed trials 1, 2, 3, 4, 5, etc., with announcement of *Right* or *Wrong* after each response.

The effect of a *Right* and a *Wrong* are compared as in the earlier experiments. Chance alone would here give 10% of rights, and 90% of any other than the one particular wrong. The results appear in Table 117. 74 and 75 refer to the same experiment, but with two different groups of subjects. Table 117 also includes the results of a similar

experiment, but with different cards as the situations and different acts as the responses (Experiment 76).*

TABLE 117

THE INFLUENCE OF ANNOUNCEMENTS OF *Right* AFTER EACH RIGHT RESPONSE AND OF *Wrong* AFTER EACH WRONG RESPONSE: EXPERIMENTS 74, 75, AND 76

	Experiments in Learning to Choose the Right One of Ten Movements			
	74	75	76	Total
Number of cases where a right response in the 1st, 2nd, or 3rd trial, but not before, was followed in the next trial				
(*a*) by a right response	10	15	12	37
(*b*) by a wrong response	12	8	5	25
Percent which (*a*) is of (*a*+*b*)	45	65	71	60
Percent due to chance	10	10	10	10
Strengthening due to one connecting in trial 1, 2, or 3 followed by *Right*	.35	.55	.61	.50
Number of cases where a wrong response in the 1st, 2nd, or 3rd trial, but not before, was followed in the next trial				
(*c*) by any other response than it	123	103	108	334
(*d*) by the same wrong response	13	17	16	46
Percent which (*c*) is of (*c*+*d*)	90	86	87	88
Percent due to chance	90	90	90	90
Weakening due to one connecting in trial 2, 3, or 4 followed by *Wrong*	0	−.04	−.03	−.02

The influence of a *Right* is substantial in each of these experiments; that of a *Wrong* is approximately zero. What influence it has is to strengthen by repetition rather than weaken by punishment. All six results for the influence of one reward versus one punishment are summarized in Table 118.

We may in a similar way compare the influence of two

* The acts in Experiment 76 were:

rub left shoulder with hand	sniff
shrug	rest head on left hand
scratch top of head	both hands up
reach for high object	drop head forward
shake head	stamp foot

TABLE 118

THE INFLUENCE OF ONE ANNOUNCEMENT OF *Right* COMPARED WITH THAT OF ONE ANNOUNCEMENT OF *Wrong*: EXPERIMENTS 71 TO 76

	71	72	73	74	75	76
Number of cases where a right response in the 1st, 2nd, or 3rd trial, but not before, was followed in the next trial						
(*a*) by a right response	283	307	326	10	15	12
(*b*) by a wrong response	338	171	218	12	8	5
Percent which (*a*) is of (*a*+*b*)	46	64	60	45	65	71
Percent due to chance	20	20	20	10	10	10
Strengthening due to one connecting in trial 1, 2, or 3 followed by *Right*	.26	.44	.40	.35	.55	.61
Number of cases where a wrong response in the 1st, 2nd or 3rd trial, but not before, was followed in the next trial						
(*c*) by any other response than it	1609	866	1272	123	103	108
(*d*) by the same wrong response	488	365	372	13	17	16
Percent which (*c*) is of (*c*+*d*)	77	70	77	90	86	87
Percent due to chance	80	80	80	90	90	90
Weakening due to one connecting in trial 2, 3, or 4 followed by *Wrong*	−.03	−.10	−.03	0	−.04	−.03

Rights with that of two *Wrongs* or of three *Rights* and three *Wrongs*. We have done so with two *Rights* and two of the same *Wrong* in trials 2 and 3, or 2 and 4, or 3 and 4, but not occurring before or in the intervening trial. The results appear in Table 119. The influence of two *Rights* is much greater than that of one. The weakening influence of two *Wrongs* is still more negative than that of one; or, more accurately, whatever forces make a response which is called wrong once appear more often than chance would prescribe in the next trial, make it appear still oftener after it has been called wrong twice.

It should be kept in mind that failure to show a greater number than chance would give of cases where a wrong response is followed in the next trial by any other response than that which does follow it, is not absolute proof of zero influence of the announcement of *Wrong*. There might be a slight influence, never strong enough to last over the interval until the next appearance of that word or card. However, the interval was only a minute or two in the case of the cards in Experiments 74, 75, and 76. Also, the re-

TABLE 119

THE INFLUENCE OF TWO ANNOUNCEMENTS OF *Right* COMPARED WITH TWO ANNOUNCEMENTS OF *Wrong*: EXPERIMENTS 71 TO 76

	71	72	73	74	75	76	Av.
Number of cases where a right response in the 2nd and 3rd, or 3rd and 4th, or 2nd and 4th trials, but not before or intervening, was followed in the next trial							
(*a*) by a right response	174	86	234	6	13	10	
(*b*) by a wrong response	73	22	59	0	0	0	
Percent which (*a*) is of (*a*+*b*)	70	80	80	100	100	100	
Percent due to chance	20	20	20	10	10	10	
Strengthening due to two connectings in trials 2 and 3, or 3 and 4, or 2 and 4, followed by *Right*	.50	.60	.60	.90	.90	.90	.73
Number of cases where a wrong response in the 2nd and 3rd, or 3rd and 4th, or 2nd and 4th trials, but not before or intervening, was followed in the next trial							
(*c*) by any other response than it	373	132	270	10	14	10	
(*d*) by the same wrong response	137	71	116	5	3	4	
Percent which (*c*) is of (*c*+*d*)	73	65	70	67	82	71	
Percent due to chance	80	80	80	90	90	90	
Weakening due to two connectings in trials 2 and 3, or 3 and 4, or 2 and 4, followed by *Wrong*	−.07	−.15	−.10	−.23	−.08	−.19	−.

sults from two *Rights* and two of the same *Wrong* indicate that some influence lasts over the interval, acting in the opposite direction to make the wrong response more likely to be given in the next trial.

So far as our results go, then, all the learning in these six experiments can and apparently must be credited to the strengthening by the announcement of *Right*. There is not a particle of evidence that the announcement of *Wrong* weakened these connections enough to counterbalance the strength they gained from just occurring. The wrong connections wane in relative frequency, not because they weaken intrinsically, but because they are supplanted by the right connections.

These results are straightforward and unanimous, but they are so contrary to the views of the majority of psychologists and so fundamental in their possible applications to economics, sociology, government, and education

that we have naturally sought to extend and vary the field of experimentation.

First we have extended the counts in Experiments 71 and 73 so as to measure the influence of three *Rights* versus three of some one *Wrong* in the same position, and to measure it in each of three ways: (1) as heretofore, by the nature of the next response, (2) by the nature of the next two responses, and (3) by the nature of the next three responses.

In learning to choose the right meanings for the Spanish words, the effect of three *Rights* in positions 2, 3, and 4 but not in 1, or in 2, 4, and 5, but not in 1 or 3, or in 3, 4, and 5 but not in 1 or 2, is as follows:

There are 186 cases of three such *Rights*. The next response (5 or 6) is right in 83%; the next two responses (5 and 6 or 6 and 7) are both right in 75%; the next three responses (5, 6, and 7 or 6, 7, and 8) are all three right in 69%.

By chance these percents would be .20, .04, and .01. There is thus a strengthening of .63, .71, and .68 according to the comparison made. The effect of one *Right* in Experiment 71 was a strengthening of .26; the effect of two *Rights* was a strengthening of .50; the effect of three *Rights* is here a strengthening of .63 by the same method of measurement.

There are 203 cases of three of the same *Wrong* in the same positions. The next response is other than that same *Wrong* in 61%; the next two are both other than that same *Wrong* in 48%; the next three are all other than that same *Wrong* in 39%. By chance these percents would be .80, .64, and .51. There is thus a weakening of —.19, —.16 or —.12 according to the comparison made. The weakening for one *Wrong* was —.03, and for two *Wrongs* —.07, as reported in Tables 118 and 119 for Experiment 71.

In learning to choose the right meanings for the rare English words of Experiments 72 and 73, the effect of three *Rights* in the positions noted above was as follows: There

are 198 cases of three such *Rights*. The next response is right in 94%. The next two are both right in 90%. The next three are all right in 87%. The strengthening over chance (.20, .04, and .01) is thus .74, .86, and .86. The effect of one *Right* in Experiments 72 and 73 was a strengthening of .44 or .40; the effect of two *Rights* was .60; the effect of three *Rights* is .74 by the same method of measurement.

There are 125 cases of three of the same *Wrong* in the positions noted above. The next response is other than the *Wrong* in question in 59% of them; the next two are both other than that *Wrong* in 48%; the next three are all other than that *Wrong* in 43%. The weakening below chance (.80, .64, and .51) is thus —.21, —.16, or —.08, according to the comparison made. The weakening for one *Wrong* was —.10 or —.03, and for two *Wrongs* —.15 or —.10, as stated in Tables 118 and 119.

We have then adequate proof that in these experiments the beneficent influence of rewarded *Rights* increases as the number of occurrences increases. We also have evidence that the difference between rewarded *Rights* and punished *Wrongs* is as clear and emphatic when we measure their influence by the next two or next three responses as when we measure it by the next one response.

Experiment 77

Six individuals learned to estimate (in square inches) the areas of a series of 74 paper surfaces, by having each of their judgments followed by *Right* or *Wrong*, announced by the experimenter.

The influence of one *Right* and that of one *Wrong* in the same position upon the next judgment are as follows: *R* produces *R* 60 times or 35% and *W* (or *not R*) 110 times or 65%. *W* produces any response other than that same *W* 1023 times or 84% and that same *W* 193 times or 16%. We estimate that the probability of making any one judgment is .13 apart from training. This estimate is made simply

by taking the 444 responses of the subjects in trial 2, omitting the 54 which were probably known from the start since they were right in both trial 2 and trial 1, counting the number of *Rights* remaining and dividing it by 390. It is thus highly arbitrary, but probably not unfair.

Using it, one *R* changes the tendency to that *R* by +.22 (.35 — .13), and one W changes the tendency to any other than that *W* by —.03 (.84 — .87).

For two *R's* and two *W's* in the same positions the facts are: Two occurrences of *R* produced *R* 41 times or 55% and *not R* 33 times or 45%. Two occurrences of the same *W* produced *not that W* 208 times or 72% and that same *W* 78 times or 28%. Two *R's* thus change the tendency to that *R* by +.42, while two *W's* of the same *W* change the tendency to *any other W than that* by —.15.

By any reasonable estimate of the expectation by chance, it will still be true that the learning occurred only by strengthening by the announcements of *Right*, the wrong responses doing more harm by occurring than good by being punished by *Wrong*.

Experiment 78

In the experiment in completing words* we have measured the influence of two rights rewarded by *Right* in positions 1 and 2, or 2 and 3, or 3 and 4 upon the next eleven responses to the situation in question; and similarly for two occurrences of any one wrong response punished by *Wrong* in these same positions. We used the responses to empty spaces following a, b, c, d, e, f, and g. Two *Rights* are followed by eleven rights in sequence 27 times out of 58, or in 47%. The chance for such a sequence of eleven cannot be computed but is surely inappreciable. Two occurrences of a *Wrong* are followed by eleven responses other than that wrong in one case out of 58. Here again the influence of two *Rights* is clear and large. That of two *Wrongs* is dubious and near zero.

* Experiment 56 of Chapter X.

The conclusions reached from these comparisons are supported by comparisons of the following sort:

We ask concerning one or two or three *Rights* and one or two or three cases of a certain *Wrong* in the same positions (not occurring in earlier or intervening positions in either case) whether *all* the responses after the last of these rights are right and whether *all* the responses after the last of these occurrences of the given wrong are other than that particular wrong. For example, in Experiment 77 in judging areas, two *Rights* were followed by all rights in 60 out of 139 cases or 43%, and three *Rights* were followed by all rights in 34 out of 58 cases or 59%. Two of the same *Wrong* in similar positions were followed by all other than that Wrong in 58 out of 279 cases, or 21%, and three of the same *Wrong* were followed by all other than that Wrong in 4 out of 55 cases or 7%. Since there were ten or more trials following, the probability of obtaining all rights by chance is infinitesimal (on the average about $.13^{12}$). The probability of obtaining all other than the one particular wrong by chance is small (about $.87^{12}$), but if the rights increase by learning as they do, they increase the chances for responses other than that wrong (or any wrong). The fact that three occurrences of a *Wrong* strengthen the avoidance of that wrong less than two occurrences do, means probably that both really weaken it.

A reasonable rough estimate for this case of area judgments is that the tendency for any one wrong never to appear after the amount of training in which two or three occurrences of it have appeared is about .20 by chance, but is increased to over .30 by the increased strength of the right judgment. Two or three occurrences of it punished by *Wrong* strengthen the connection leading to it more by their frequency than they weaken it by being punished, so that we have the .21 and .07 instead of .30 or more.

In Experiment 78, where ten simple acts were associated with ten easily distinguishable signals, we have measured the effect of two *Rights* (in positions 1 and 2, or 1 and 3, or

2 and 3), and that of two *Wrongs* in the same positions, upon the *four* following responses to the same situations. Two *Rights* produce all rights in the next four responses 31 times out of 37, or in 84% of the cases. The probability by chance of four such is .0001. Two cases of *Wrong* produced some response other than that particular wrong in the next four responses 32 times out of 52, or in 62% of the cases. The chance of four such would be .48 except for the infusion of rights where the correct response was wholly or partly learned during the next four. This raises it considerably, since the learning was rapid. Probably the influence of the two *Wrongs* is not far from zero.

Experiment 79

By the courtesy of Mrs. Josephine R. Knowles, we have been furnished the detailed records of the responses of 80 persons to every one of the ten situations in her maze experiments which required a choice. We have computed the influence of a right (which was of course "rewarded" by free advance for a time) and that of a wrong (which was of course "punished" by a thwarting of progress shortly thereafter) upon the response to that same situation in the next trial. In the first trial, there were 404 rights and 396 wrongs, or 50½% and 49½%. Using a right in trial 1, or in trial 2 but not in trial 1, or in trial 3 but not before, or in trial 4 but not before, we have in all 675 cases, 410 of which (62%) were followed by a right in the succeeding trial. For wrong responses in the same positions as to trials, we have 641 cases, 296 of which (46%) were followed by a right, i.e., a response other than that wrong. Since the chances are .50 .50 in this experiment, one rewarded right causes a strengthening of +.12, and one punished wrong a weakening of the tendency to any other than that wrong of —.04.

The influence of two rights in trials 1 and 2, or 1 and 3, or 1 and 4, or 2 and 3, or 2 and 4, or 3 and 4, upon the response to the same situation in the next trial is measured

by 364 rights out of 499 or 73%. For two wrongs in the same positions as to trials, we have 150 sequent rights out of 431, or 35%. The influence of two thus gives a strengthening of +.23 as a result of the rights and a weakening of —.15 as a result of the wrongs.

For the influence of three rights and three wrongs in trials 1, 2, and 3 upon the response in trial 4, or in trials 2, 3, and 4 (but not before) upon the response in trial 5 we find the following: For the rights, 205 sequent rights out of 247, or 83%, a strengthening of +.33. For the wrongs, 68 sequent rights (i.e., non-wrongs) out of 203, or 34%, a weakening of —.16.

Table 120

The influence of reward and punishment in the case of human adult learning of mazes

From Data of Mrs. Josephine R. Knowles

	Trial 1		Trial 2, not before		Trial 3, not before		Trial 4, not before	
R followed by *R*	215	55%	118	66%	51	74%	26	65%
W	173		60		18		14	
W " " *R*	183	47%	69	41%	25	51%	19	58%
W	206		101		24		14	

	Trials 1+2		Trials 1+3, not in 2		Trials 1+4, not in 2 or 3		Trials 2+3, not in 1		Trials 2+4, not in 1 or 3		Trials 3+4, not in 1 or 2	
R + *R* followed by *R*	164	77%	44	65%	17	55%	86	73%	13	68%	40	78%
W	48		24		14		32		6		11	
W+*W* " " *R*	66	33%	20	34%	15	50%	32	31%	11	44%	6	35%
W	132		38		15		71		14		11	

	Trials 1 + 2 + 3		Trials 2 + 3 + 4, not in 1	
R + *R* + *R* followed by *R*	129	79%	76	90%
W	34		8	
W + *W* + *W* " " *R*	43	33%	25	34%
W	86		49	

The detailed facts are given in Table 120 for the sake of any reader who wishes to make sure that these results are not seriously prejudiced by overweighting of right and wrong responses which for some mysterious reason may have been specially strong. It will be observed that the

facts for cases where the tendency to R or W may have been specially strong (R or W in trial 1, $R + R$ or $W + W$ in trial 1 and 2, and $R + R + R$ or $W + W + W$ in trials 1, 2, and 3) are not notably different from the rest in showing greater learning from rights than from wrongs.

Measuring the influence of two rights and two wrongs in trials 1 and 2 or in 2 and 3 but not in 1, or in 1 and 3 but not in 2 upon the next four trials, we find that the two rights are followed in 183 of the 393 cases, or 47%, by four successive rights, whereas the two wrongs are followed in 15% of the 359 cases by four successive rights (which are here the same as four other than the particular wrong). The chance for a right at this stage of the learning (trials 3, 4, 5, 6, and 7) is, by actual count, .56 in trial 3, .57 in trial 4, .61 in trial 5, .62 in trial 6, and .63 in trial 7. So the chance for four successive rights in positions 4, 5, 6, and 7 by chance is about .14. This leaves a strengthening of .34 as a result for the two rights and of .01 for the two wrongs.

If we use .50 as the chance, disregarding the learning which goes on in these early trials, the strengthening would be, of course, .41 for the two rights and .09 for the two wrongs. But to do so is obviously unfair since it credits the two wrongs with not only their own influence but also that of the intervening or sequent rights; and we know from our other records that a right has more influence than a wrong.

*Experiment 80**

The subject sat with eyes bandaged and drew lines at the commands, *Draw 3 inches, Draw 4 inches, Draw 5 inches, Draw 6 inches.* He drew each line with one quick shove of the pencil. During the tests (each comprising five of each sort in a random order except that there were no sequences) he had no knowledge of his success. During the training periods the announcement of *Right* or *Wrong* was made after each line had been drawn, according as the line was

* Same as Experiment 45 of Chapter IX.

or was not within ¼ inch of the correct length (⅛″ for 3″ lines). These announcements were not infallible. The subject always started from a straight edge, parallel to which lines were ruled at 2¾, 3¼, 3¾, 4¼, 4¾, 5¼, 5¾, and 6¼ inches. If the end of his line came within the appropriate parallels, it was called right. Slanting lines were thus occasionally called right, though really slightly too long or too short, and were occasionally called wrong, though really within ¼ inch of the length.

Each day's program consisted of a test of 20, a training of 100, a test of 20, a training of 100, and so on until time was up. The general effect of the training was to improve the ability, chiefly by the reduction of constant tendencies to draw lines too short.

Our present concern is with the comparative effects of the *Right* and *Wrong* announcements. We wish to measure the extent to which an announcement of *Right* after a response called correct makes the next response to that same command more often the correct response than it would have been apart from that announcement, and the extent to which an announcement of *Wrong* after a certain sort of wrong response, say of 1.3 to 1.9 inches (the command being *Draw 3 inches*) makes the next response to that same command less often a line of 1.3 to 1.9 inches, or more often a line other than that, than it would have been apart from that announcement.

We may estimate the probabilities apart from the announcement by the records in the test series. For example, in test 1 of day 3, individuals Bi, Ly, DM, and Ha responding to *Draw 6 inches*, drew lines as shown below:

	Bi	Ly	DM	Ha
3.6 to 4.2 inches				
4.3 to 4.9 inches				4
5.0 to 5.6 inches	1		3	1
5.7 to 6.3 inches		2	1	
6.4 to 7.0 inches		3	1	
7.1 to 7.7 inches	4			
7.8 to 8.4 inches				

The expectation for the lines drawn at the command *Draw 6 inches*, if the test had been extended to another twenty lines, would be the same as that in the test.

We measure the effect of the announcements after the first five six-inch tasks of the practice. For example, Bi's first six records for six-inch commands are in order: 7.0, 6.6, 8.1, 7.3, 7.2, and 6.8, the first five being, of course, punished by wrong. A response in the group 6.4 to 7.0 occurred twice in these first five, and was followed once by a response in the same group and once by a response in a different group. It produced a response in a different group in 50% of the occasions, or 50% less than expectation, which was 100%. A response in the 7.1 to 7.7 group occurred twice in the first five and was followed once by a response in the same group and once by a response in a different group. The 50% of "other than that response" is here 30% more than expectation, which was 20%. A response in the 7.8 to 8.4 group occurred once and was followed by a response in a different group. The 100% is here the same as expectation. We have, then, for the effect of the punishment from those three computations, one case of strengthening the connection, one of weakening it, and one of zero influence.

DM had records, in order, of 6.2, 6.0, 6.0, 5.8, 5.1, and 6.0. The four responses of the first five that were rewarded by *Right* were followed severally by three in the same group and one in a different group. The 75% was 35% above expectation, which was 40%. The punished connection (5.1) was followed by a response (6.0) in a different group in 100% of its occurrences, which is 60% more than expectation. We have for the two computations from DM's records a *Right* producing a strengthening, and a *Wrong* producing a weakening.

Combining these with the results of similar computations from twelve other subjects in the case of the influence of six-inch lines 1 to 5 upon six-inch lines 2 to 6 of the prac-

tice immediately following test 1 of day 3, we have the following:

Rewarded connections occurred in ten individuals, and were followed by connections leading to responses between 5.7 and 6.3 more often than expectation in 5, as often as expectation in 3, and less often than expectation in 2. Reward strengthens the rewarded connection, if these results are typical. Punished connections (in groups 3.6 to 4.2, 4.3 to 4.9, 5.0 to 5.6, 6.4 to 7.0, 7.1 to 7.7, and 7.8 to 8.4) occurred in thirteen individuals, permitting 22 comparisons involving one or more responses. They were followed by connections leading to a response in the same group more often than expectation in 8, as often as expectation in 8, and less often than expectation in 6. Punishment does *not* weaken the punished connection (or strengthen all others than it), if these results are typical.

We have made such records and computations for the influence of trials 1 to 5 upon trials 2 to 6, respectively, in the case of 3″, 4″, 5″, and 6″ lines following test 1 of day 1, test 1 of day 2, and test 1 of day 3. The total result for connections rewarded by *Right* is that the sequent connection was in the same group more often than expectation in 50 cases, as often as expectation in 14 cases, and less often than expectation in 33. In percents, we have 51½, 14½, and 34. The total result for connections punished by *Wrong* is that the sequent connection was in the same group more often than expectation in 124 cases, as often as expectation in 86, and less often than expectation in 118. In percents, we have 38, 26, and 36. Dividing the "as often" cases equally between the "more often" and the "less often" we have:

Rewarded connections: positive, 59; negative, 41.
Punished connections: positive, 51; negative, 49.

The rewarded connection is thus strengthened by the reward, but the punished connection is not weakened by the punishment. If we take the figures at their face value, it is on the contrary strengthened a wee bit by the repeti-

tion in spite of the punishment. These exact percents are, of course, not highly reliable, but the chances are over 99 to 1 that the rewards had a greater influence in strengthening than the punishment had in weakening the connection.*

We may use a more rigorous treatment by using the influence of only the first trial upon the second. The totals for the sequents of rewarded connections are 21 in the same group more often than expectation, 11 as often as expectation, and 12 less often than expectation. Corresponding figures for the sequents of punished connections are 49, 25, and 50. Dividing the cases which show zero difference from expectation equally between the "more" and "less" we have:

Rewarded connections: positive, 60; negative, 40.
Punished connections: positive, 50; negative, 50.

There is thus close correspondence with the results obtained by using five trials.

In this experiment, then, although the subjects occasionally deliberately shove harder or less hard after a *Wrong* or series of *Wrongs*, the net result is that the occurrence of a connection plus punishment does as much harm by the connection's occurring as it does good by stimulating the subject to change his response. There is not a particle of evidence to show that it directly and inevitably weakens the connection to which it belongs. The learning seems entirely due to the strengthening of the rewarded connections.

We have data on our general problem in the records of Kuo's thirteen rats ['22], in whom four different connections in a multiple-choice experiment had as respective after-effects:

c (confinement for 20 seconds)
e (an electric shock)

* The results for the three separate periods in order are: Positive effect of reward, 58%, 51%, and 65%; negative effect of punishment, 51%, 48%, and 47%. The average difference is 9.3, with a mean square error of 3.6+. The difference is thus over two and one-half times its mean square error or nearly four times its P.E.

l (food after a long path had been traversed—about twelve feet)
s (food after a short path had been traversed—about one foot)

"If the electric shock or the confinement compartment were chosen, the experimenter immediately lowered the front door and, in the former case, pressed the key outside the maze thus giving the animal a shock, or, in the latter case, confining him in the compartment for *twenty* seconds. The electric shock was strong enough to make the animal squeal every time and immediately jump back* from the compartment after the shock was given." [Kuo, '22, p. 8.]

TABLE 121

RESPONSES OF 13 RATS IN SUCCESSIVE TRIALS WITH KUO'S MULTIPLE-CHOICE APPARATUS

c, *e*, *l*, and *s* signify, respectively, entrances to the compartments where confinement, an electric shock, a long path to food, and a short path to food were the consequences

1	cles esel escl esss cece lcss clcs scls lcsl sssl cssl slls ssll slcl s
2	lele seee llec csce sell eelc scsc cecl elll lcss slll llls llll sssl s
3	eses eecs leel cesc sses ssll eclc ssss csls ssss ssss ssss ss
4	scel clel llel lscs llsl llcl lssl llcs llcs ssls lsss lsss ssll ssss s
5	cesc sele cscl sccs slcl slcs slls ssll slll llls llsl lsll llsl lcss l
6	ecse sses scll elll ssss ssss ssss sls
7	celc ells slll lsll ssll cssl llll essl llll lsls sssl ssss ssss ssss s
8	scse sssl llec lles ssss ssss ssss s
9	clel esll elss ssss ssss ssss s
10	lesc ssll llll llcl llll llll llll llll llll lll
11	scsl elll slss scls llsl lssl ssls ssss ssss ss
12	sell clec llll llll clll llll llll llll llll llll l
13	lels clel cels ssss cscs slcl ssss ssss ssss sss

Continuation of the above

1	csss sssc llll cssl lsls llls ssss ssss ssss ss
2	ssls lsls ssss ssss ssss ss
4	ssss ssss ss
5	llss ssss ssss ssss s
7	ss

* This jumping *back* was apparently in preliminary tests. Since the door was closed behind him in the actual trials, he must, if he then jumped anywhere, have jumped forward.

The responses for each rat in order, identified by these letters denoting their after-effects, are shown in Table 121. It is evident first of all that *l* had in general a positive value strengthening *l*, not *non-l*. For example in rats 10 and 12, twenty-four occurrences in sequence did not weaken it. In rats 2 and 5 it maintained itself in competition with *s*. It is never displaced for any long period save by *s*. It appears also that in the early trials, especially the first four, there is a mixture of (a) tendencies of *s* to wax and *c* and *e* to wane with (b) an exploratory tendency to try a new response. There is only one sequence of *ll* or *ss* in the fifty-two of the first four trials whereas chance alone should give three. Finally, it appears that *c* produces a negative effect which is large for the time being but does not last long. Out of forty-four occurrences of *c* in the first twenty-four trials, only one was followed by *c*, but *c*'s occur almost as often in the second twelve trials as in the first twelve.

Moreover the learning of most of these rats does not seem to have been chiefly by the gradual favoring of *l* or *s* or elimination of *c* and *e*. For example, if we record the results for subjects in successive fours, we have:

for rat	3,	2	1	0	1	3	2	0	4	2	4	4	4	4	
"	6,	1	3	1	0	4	4	4							
"	7,	0	1	1	1	2	2	0	2	0	2	3	4	4	4
"	8,	2	3	0	0	4	4	4							
"	9,	0	1	2	4	4	4								
"	11,	2	0	3	2	1	2	3	4	4					
"	13,	1	0	1	4	2	1	4	4	4	4				

The number of the *s* responses in a set of four just preceding a straight sequence of twelve or more *s*'s was only 2, 0, 3, 0, 2, 3, and 1, respectively. If we compare the first and second and third fours for these rats, all of whom eventually responded by *s*, we find averages of 1 1/7, 1 2/7, and 1 1/7.

Continuing the records of Table 121 for rats 1, 2, and 4, who learned eventually to respond by *s* or *l* 19 times out of 20, the number of *s* and *l* in successive fours averaged 2,

1 2/3, 2 1/3, 2 1/3, 2 1/3, 2 1/3, 2 2/3, 2 1/3, 3, 3 2/3, 3 2/3, 4, 4, and 3 2/3.

Rats 10 and 12, who both showed runs of thirty-two *l*'s broken only by a single *c*, began these after *l e s c s s* and *s e l l c l e c*.

The general picture is not of a gradual selection or elimination by each rat, but rather of exploration, resulting acquaintance with the environment as a total, expectations aroused by the four entrances, sudden formation of desirable habits by some rats and slow formation of any habits by others.

As a result of these facts and also of the scantiness of the data, we cannot profitably use the same rigorous methods as were used in the cases of human learning. We shall use makeshifts each of which has deficiencies. We shall keep these in mind in drawing conclusions.

We first compare *s* with *e*. Using any two occurrences of *s* in the first eight trials we find the following trial to be an *s* in 10 cases out of 22, or 46%, or +.21 more than chance expectation. Using three such occurrences, we have an *s* following in 4 cases out of 9, or 44%, or +.19. Using four occurrences, we have an *s* following in 2 cases out of 2, or 100%, or +.75. For two, three, and four occurrences of *e* in the first eight, the following trial shows a *non-e* in 20 out of 27, 5 out of 9, and 1 out of 2, or 74%, 56%, and 50%, or —.01, —.19, and —.25, respectively. The assumption that, apart from the effect of learning, there would be approximately 25% of each response is justified by the facts for the first four trials in which *c, e, l,* and *s* occurred 11, 15, 13, and 13 times, respectively. In later trials, as a result of learning, the expectation for *s* rises, but so does that for *non-e*.

The electric shock after a certain connection thus has apparently not enough weakening effect to make up for the strengthening that connection acquires by occurring. This conclusion can be checked by comparing the effect of 5 *s*'s in the first twelve trials upon the entire status in the next

twelve with the effect of 4 or 6 *e*'s in the first twelve trials upon the entire status of the next twelve. Three cases of 5 *s*'s in 1 to 12, are followed in 13 to 24 by 1 *c*, 2 *e*, 11 *l*, and 22 *s*, or an average of 61% of *s*. One case of 4 *e* and two cases of 6 *e* in 1 to 12 are followed in 13 to 24 by 8 *c*, 9 *e*, 6 *l*, and 13 *s*, or an average of 75% of *non-e*. So the 5 *s*'s are followed by a strengthening of +.36 for *s*, and the 5 1/3 *e* are followed by a weakening of 0 for *non-e*.

As a third method of comparison we may count up to three or four or five or six occurrences of *s* and then examine the entire status in the next four or eight or twelve trials; and similarly for *e*. The results (using the twelve following trials) are 35% of *s*, 36% of *s*, 41% of *s*, and 48% of *s*, for two- three, four, and five occurrences of *s*. There are 85%, 88%, 79%, and 75% of *non-e* for two, three, four, and five occurrences of *e*. Using .25 and .75 as the expectation by chance, we have strengthening of .10, .12, .16, and .23 for two, three, four, and five occurrences of *s*, and strengthening of .10, .13, .04, and .00 for two, three, four, and five occurrences of *e*.

On the whole it appears that the *e* connection was not weakened by the electric shock but was simply supplanted by the *s* and *l* connections. The average of all our determinations gives an effect of *e* of —.02; the median is .00.

We next compare *s* with *c*. The first method gives very, very scanty results, there being only four instances of 2 *c*'s in the first eight trials. The sequent response was always a *non-c*. Using the second method, we find one case of 4 *c*'s in the first twelve, which was followed in the second twelve by 67% of *non-c*, to be compared with 75% by sheer chance.

Using the third method, we find 90%, 84%, 76%, and 82% of *non-c* in the twelve following 2, 3, 4, or 5 *c*'s. On the whole, the confinement seems to have had little effect upon the *c* connections, but the data are too scant to justify any sure conclusion. The median of our determinations is .08.

Considering the after-effects of *e* and *c* both, we have a general agreement with our previous results that the effect

of an annoying sequel is very weak in comparison with the effect of a satisfying sequel. The average strengthening of *non-e* and *non-c*, two or three occurrences of *e* or *c*, respectively, was .07; for four or five it was 0.2. I repeat the warning made earlier that the learning as a whole does not appear to be the product of any simple and regular strengthening or weakening.

We may now review the essential results of the admirable experiments of Warden and Aylesworth ['27],* which are, in some respects, in contrast with those so far reported in showing a greater influence of punishment as an aid to learning. They arranged an apparatus so that if the animals (white rats, three months old) entered a passageway marked by a bright patch of light (from a 75-watt Mazda bulb), they received an electric shock from a grid on the floor. If they entered a passageway marked by a much less bright patch, they received no shock, and in the case of "reward" experiments "a nibble of milk and soaked bread."

There were three series of experiments. In the *Reward Series* (R) the right response was rewarded and the wrong response was followed by removal of the rats from the goal box and (presumably) transfer to their regular home cage or some resting place. In the *Punishment Series* (P) the right response was followed as the wrong one was in the series R, and the wrong response was followed by the electric shock and then by removal from the pen and (presumably) transfer as above. In the *Reward and Punishment Series* (RP) the right response was rewarded as above and the wrong response was punished as above.

At the beginning eight out of ten rats in each group "showed a preference for the illuminated patch or no preference at all" in twenty trials with food in both compartments and no shock, "the other two showing only a slight preference for the dark patch" ['27, p. 120].

* Hoge and Stocking ['12] have reported results in substantial agreement with those of Warden and Aylesworth.

The ten rats of R progressed toward favoring the "right" passageway very slowly, attaining a status of 9 right choices out of 10 in an average of 293.5 trials. The ten rats of series P progressed much faster, attaining this status after an average of 56.2 trials. The ten rats of series RP progressed still faster, attaining the same status after an average of 32.8 trials. A status of 18 right choices out of 20 was attained by the P rats in 104.4 trials, and by the RP rats in 59.7 trials. A status of 27 right choices out of 30 was attained by the P rats in 145.9 trials and by the RP rats in 67.3 trials.

The rats that were punished by the shock responded often thereafter by entering neither passageway, but staying in the reaction chamber. If one did this for five minutes, his trial was counted a failure, and he was removed as above. If the learning task had been *not* to enter the wrong passageway, the punished rats would have surpassed the fed rats even more. The reward-punishment rats may be said to have been taught by the punishment to avoid the wrong passageway, and by the reward to avoid staying for five minutes in the reaction chamber, as well as to go to the right passageway.

We cannot put the records in this experiment into direct comparison with those hitherto discussed because we have not the individual records of the thirty animals.*

The average history in somewhat more detail is shown in Table 122 (computed from Table 1 of Warden and Aylesworth). The contrast between these results and those which we have reported is really not so extreme as might be supposed. The slowness of the learning in the R series may well be due to the fact that we have a differential between two rewards; release plus food and release alone. The learning of the P series may be explained without supposing that the shock weakens anything directly. It may simply strengthen the tendency to stay in the reaction chamber.

* Dr. Warden has been good enough to search his files for these, but none of them were preserved.

TABLE 122

THE NUMBER OF RIGHTS (D), WRONGS (L), AND 5-MINUTE DELAYS (NR) PER RAT ON EACH DAY

	R Series		P Series			RP Series		
	d	l	d	l	nr	d	l	nr
1	1.5	3.5	2.1	2.2	0.7	1.7	3.1	0.2
2	1.4	3.6	0.5	0.5	4.0	2.0	1.3	1.7
3	1.8	3.2	1.2	0.7	3.1	2.1	1.3	1.6
4	1.6	3 4	2.2	0.9	1.9	3.1	0.9	1.0
5	1.9	3.1	2.3	0.9	1.8	3.4	1.0	0.6
6	1.6	3 4	2.8	0.7	1.5	3.2	1.5	0.3
7	2.2	2 8	2.6	0.4	2.0	4.2	0.7	0.1
8	4.2	5.8	5.7	1.1	3.2	8.4	1.5	0.1
9	4 5	5 5	5.1	0.7	4.2	8.0	2.0	0.0
10	4.7	5 3	5.5	1.0	3.5	9.5	0.5	0.0
11	4.3	5.7	5.9	0.6	3.5	8.6	1.2	0.2
12	4.7	5.3	5.6	0.4	4.0	8.7	1.0	0.3
13	4.8	5 2	5.4	0.6	4.0	9.0	0.0	1 0
14	4.5	5.5	7.1	0.9	2.0	10.0	0.0	0.0
15	5.4	4.6	6.7	1.2	2.1	10.0	0.0	0.0
16	4.7	5.3	8.0	1.0	1.0			
17	4.8	5.2	8.6	0.6	0.8			
18	5.2	4.8	7.5	1.3	1.2			
19	5.5	4.5	6.0	1.2	2.8			
20	5.7	4.3	8.5	1.2	0.3			
21	6.3	3.7	8.3	0.7	1.0			
22	5.8	4 2	8.0	1.5	0.5			
23	5.2	4.8	8.0	1.0	1.0			
24	4.9	5.1	7.0	2.0	1.0			
25	5.8	4 2	10.0	0.0	0.0			
26	5.1	4.9	7.0	3.0	0.0			
27	8.3	6.7	5.0	4.0	1.0			
28	8.6	6.4	5.0	3.0	2.0			
29	8.6	6.4	8.0	2.0	0.0			
30	9.0	6.0	9.0	1.0	0.0			
31	9.0	6.0	7.0	3.0	0.0			
32	8.3	6.7	8.0	1.0	1.0			
33	8.6	6.4	10.0	0.0	0.0			
34	8.4	6.6	10.0	0.0	0.0			
35	9.2	5.8						
36	8.6	6.4						
37	9.3	5.7						
38	8.3	6.7						
39	9.2	5.8						
40	9.8	4.2						
41	9.3	5.7						

Suppose, for example, we set the initial strengths as:

.30—To go through the dark-spot passage (*d*)

.70—To go through the light-spot passage (*l*)

.00—To stay for five minutes or more in the chamber (*nr*)

and that we set the effects as:

One feeding, .20 for *d*.

One release with no feeding, .12 for *d* or *l*, as the case may be.

One shock, .10 for *nr*. (Note that the shock does nothing to *l*, by hypothesis).

One staying in the reaction chamber for five minutes, .05 for *nr*.*

At the end of day 10, i.e., after 65 trials (Table 123), we then should expect in the R series to have relative strengths of .50, .50, and 0, or $\frac{5.38}{10.83}$, $\frac{5.45}{10.83}$, and $\frac{0}{10.83}$ for *d* and *l* and *nr*. These are derived from

$$\frac{.30 + 25.4 \times .20}{.30 + (25.4 \times .20) + .70 + (39.6 \times .12)}$$

and $.70 + (39.6 \times .12)$ over the same denominator, and 0

TABLE 123

THE NUMBER OF RIGHTS (D), WRONGS (L), AND 5-MINUTE DELAYS (NR) PER RAT IN DAYS 1 TO 7 (FIRST 35 TRIALS) AND IN DAYS 1 TO 10 (FIRST 65 TRIALS)

		R Series		P Series			RP Series		
		d	l	d	l	nr	d	l	nr
Trials	1–35	12.0	23.0	13.7	6.3	15.0	19.7	9.8	5.5
"	1–65	25.4	39.6	30.0	9.1	25.9	45.6	13.8	5.6

* The computation of strengths presented here is exceedingly crude and is presented more to illustrate the argument in general than to support it in detail. For the latter purpose, we should compute expected and obtained strengths at more points in the series, and consider probabilities of changes in the amount of strengthening for a feeding or a shock as the series progresses. Any such calculations of strengths and of the changes in them produced by certain occurrences with or without certain after-effects rest upon insecure assumptions, and are far from satisfactory. Analyses of this sort are, however, important as a method of studying learning, and even poor ones are better than none.

I am encouraged to recommend them because Hull ['30, pp. 244-255] has independently devised analyses of this type, and finds them profitable.

over the same denominator. We actually have, on days 11 and 12, .45 for *d* and .55 for *l*, and 0 for *nr*.

In the P series, after day 10, we should expect to have relative strengths of *d, l,* and *nr* of .57 +, .10, and .32+. These are derived from

$$\frac{.30 + 30 \times .12}{.30 + (30 \times .12) + .70 + (9.1 \times .10) + (25.9 \times .05)};$$

.70 over the same denominator; and $0 + 9.1 \times .10 + 25.9 \times .05$ over the same denominator. We actually have, on days 11 and 12, 57½, .05, and .37½.

With the RP series, however, these simple strengthenings do not prove satisfactory. The results expected by the .20, .12, .10, .05 system are .80, .06, and .14; the results actually found on days 11 and 12 are .86½, .11, and .02½. Either the food plus release is more potent when in contrast with the shock, or the shock teaches the animal now to jump back and stay in the chamber and at other times to jump ahead, or the shock teaches the animal either to stay in the chamber or to go through the dark-spot passage.

Our explanation of the difference between these results and those of Kuo is that in the Warden-Aylesworth experiments the rats could respond to the shock by going back out of the shock passage and into the reward passage whereas in Kuo's experiments they could not, because the experimenter "immediately lowered the front door." [Kuo, '22, p. 8.] Kuo's account does not make it clear how the rats, after shock or confinement, reached the entrance chamber for the rest of the "trial." Presumably they went around by the outside passage or were put back by the experimenter.

The shock in the Warden-Aylesworth experiments thus added to the sequence, *presence in entrance chamber* → *choice of light-spot passage* → *shock*, the sequence, *choice of light-spot passage* → *shock* → *return to entrance chamber* → *freedom from shock*. We thus have a response other than the "wrong" one actually exercised and, in a sense,

rewarded. If the animal, after the shock, runs back out of the light-spot passage and into and through the dark-spot passage, he is very emphatically rewarded.

A fairly careful search of the literature on human and animal learning has failed to find further material suitable to measure the comparative influence of rewards and punishments.* The least unsuitable records are those of Co-

*Dodson ['17] tried to compare the influence of reward and punishment, but what he really did was not that. He used a discrimination apparatus and possibly when the first choice (under conditions of reward) was wrong, the animal got the food almost as soon as if he had chosen correctly. "*Training with food.* At the beginning of the series of experiments with food, food was placed in the receptacles. . . . If the subject chose the light box it found toasted corn flakes soaked in cream in the food receptacle. The rat was given about ten seconds in which to eat, then the experimenter made it pass on through the alley into the nest box ready for another trial. If the animal chose the dark box it found the door closed and had to return into the entrance chamber and pass out through the light box." ['17, pp. 240f.]

Dodson does not tell us what we need to know, namely, whether, on then passing through the light box, the animal was allowed to eat, or if not, how it was restrained from doing so; nor does he tell us how long it was before this animal was tried again. This could not have been more than six minutes on the average and may have been very much less. We have, then, in his report no clear statement of the difference between consequences of entering light versus entering dark. Presumably the animal was not fed after traversing the light box when it first traversed the dark. Otherwise the experiment would be simply on getting food a little later. But if it was not allowed in such cases to feed after traversing the light box, there must have been some prevention by the experimenter; and this presumably would be a serious disturbing factor. The choice of light would bring the animal to the food and let it eat; the choice of dark would bring it to the food later but not let it eat. So some of the total entrances to light would have very different results from others.

The rats took longer to learn by this training than by being given electric shocks and forced thereafter to go back out of the dark box and into the light box if they chose dark, and by being given a peaceful passage to the nest box if they chose light. But this fact does not permit useful comparisons of the food with the shock.

We have the following:

Experiments with food in the receptacle and no shock, with rats deprived of food for 31 to 48 hours.

If choose light, food and peaceful passage to nest box.

If choose dark, return after undefined time to entrance chamber, then entrance to light box (presumably being restrained from eating there), then passage to nest box.

burn and Yerkes ['15] for crows, and ['15] for pigs, those of Yerkes ['16] for monkeys, and those of Sadovinkova ['23] for canaries. We have submitted these to three sorts of treatment. The first is to use as close an approximation to the method used for our human data as is possible. The second is to apply hypothetical amounts of strengthening and weakening (as illustrated above in the case of the Warden-Aylesworth data) by two systems, one giving considerable influence to punishment in the way of weakening the punished connection (or strengthening all the others than it, which were available to the animal), the other giving little or none. The third is to compare the sequents of the first 2 or 3 or 4 or 5 or 6 correct connections with those of the first 2 or 3 or 4 or 5 or 6 of any one specified

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Experiments with no food but with shock, with rats deprived of food for only a very few hours.

If choose light, peaceful passage to nest box.

If choose dark, shock, return (presumably immediate) to entrance chamber, then entrance to light box, then passage to nest box.

The comparisons within the different degrees of shock and within the different lengths of time since the last feeding are the only useful ones. A moderate shock favors learning most. With 60 units of shock, 73 trials were required; with 75 units, 39 trials; with 115 units, 54 trials; with 150 units, 58 trials. [Dodson, p. 261.] Up to 41 hours, the longer the animals were without food, the more quickly they learned to choose the light box exclusively. The 48-hour group were much slower [24 hr., 129 trials; 31 hr., 86 trials; 41 hr., 75 trials; 48 hr., 137 trials.]

Dodson ['15] found that an increase in the intensity of the electric shock used as punishment was favorable to learning when the discrimination to be learned was easy. The number of trials required on the average to perfect a correct habit in each case was as shown below.

	Weak	Medium	Strong
Difficult discrimination	..	82.5	107.5
Less difficult "	..	60	55
Easy "	75	50	35

In the experiments of Bunch ['28] a strong shock given at the end of each cul de sac reduced errors in human subjects learning a maze, partly by making them much more cautious, partly by its informative influence, and partly, presumably, by inclining them to turn and go back at certain places. We have no means of separating these three lines of influence, or of determining how far proceeding without receiving the severe shocks may have come to be a potent satisfier.

wrong connection, disregarding what other connections also operated during the period which provided the 2 or 3 or 4 or 5 or 6 connections in question.

The net result of these elaborate analyses and computations (summaries of which are given in Appendix V) is to show that the reward (food and freedom from experimentation for the time being) did strengthen the connection between the situation and the rewarded act of entering a certain door, but that the punishment (confinement in a small dark box for 15 to 60 (usually 30) seconds followed by return to the experimental situation) weakened only slightly the connection between the situation and the response of entering that particular wrong door.

It will not be hard for anyone to test our hypotheses by further experiments with animals. All that is required is experiments of the multiple-choice type, preceded by, say, twenty trials with no consequences whatever, to obtain the strength of the various tendencies apart from any reward or punishment. The experiments with reward or punishment or reward and punishment need not be carried beyond a few trials, but everything save the reward or punishment should be carefully equalized, and all the relevant responses of the animal should be recorded. Many individuals must be tested.

We are led by all these results to these general facts and principles:

First, a satisfying after-effect which belongs to a connection can be relied on to strengthen the connection.

Second, an annoying after-effect under the same conditions has no such uniform weakening effect. In certain cases, known by general observation or displayed in experiments such as those of Hoge and Stocking and of Warden and Aylesworth, an annoying after-effect does weaken the tendency which produces it.

Third, when it does so, its method of action is often, perhaps always, indirect. That is, the person or animal is led by the annoying after-effect to do something else to the

situation which makes him later less likely to follow the original connection.

Fourth, what he is led to do directly is often (1) either to make a native or acquired response to the particular annoyance in question (as when he responds to annoyance at a certain place by leaving that place, or to annoyance by a certain object by avoiding that object, or to annoyance in the mouth by spitting out the mouth's contents), or (2) to have an idea or other awareness of the undesirability of such and such behavior (as when he responds to a *Wrong* heard after saying that 9 × 8 are 78 by thinking *"78 is not good to say for 9 × 8"*).

Fifth, what an animal is led to do directly by an annoyer need not make him later less likely to follow the original connection. For example, let an animal that has learned to choose exit A rather than B or C or D from a certain pen nine times out of ten because A has meant rest and food whereas B, C, and D have meant only rest, be given, the next time it enters B, a violent electric shock, producing a panic of agitation and terror. Then in later trials the animal may be so agitated and panic-stricken when put in the pen that it is as likely to go to exit B as to exit A, increasing the frequency of that error from .10 to .25.

The influence upon learning of both satisfiers and annoyers depends upon what they cause the animal to be or do. A satisfier which is attached to a modifiable connection always, or almost always, causes the animal to be or do something which strengthens the connection to which the satisfier is attached; but we do not know what this something is. It may be to maintain relatively undisturbed the physiological basis of the connection; it may be to retain it longer than would otherwise be the case; it may be to confine it by some metabolic effect; it may be to alter it in some more mysterious way.* An annoyer which is attached to a

* The satisfying after-effect obviously often causes the animal then and there to continue or repeat the connection. But this influence via immediate continuation or repetition is different from that with which we have been concerned.

modifiable connection may cause the animal to feel fear or chagrin, jump back, run away, wince, cry, perform the same act as before but more vigorously, or whatever else is in his repertory as a response to that annoyer in that situation. But there is no evidence that it takes away strength from the physiological basis of the connection in any way comparable to the way in which a satisfying after-effect adds strength to it.

The facts which we have presented in previous chapters demonstrate the strengthening influence of satisfying after-effects, and the facts presented in this chapter demonstrate that annoying after-effects are not dynamically opposites of satisfiers, but are specialized in their action. Our facts should be only the beginning of an extensive and searching inquiry. The influence of rewards and punishments is of enormous practical importance. If the facts which we have presented are accurate and if the conclusions which we have drawn from them are correct, the cause or causes of the favorable influence of a satisfier are also of great theoretical importance since they presumably operate in all selective processes, including problem-solving and reasoning.

We hope in later investigations to do justice to the practical problems of when and how to reward and when and how to punish, in all spheres of human management, and to the fundamental science of modifiability by satisfiers and annoyers.

CHAPTER XII

The Physiological Basis of the Strengthening of Connections by Their After-Effects

How the after-effect of a connection strengthens it is not known. We do not even know what physiological events correspond to an increase in the strength of a connection or to satisfyingness. Indeed we do not know with surety what physiological event corresponds to a connection at any strength, though the evidence that it is some condition favoring conduction across certain synapses is still strong.* Physiological explanations of the potency of either the repetition of a connection or the satisfyingness of its consequences are therefore necessarily speculative, and perhaps unprofitable.† We shall say little about them, and that little will consist chiefly of facts which are intrinsically valuable.

It is sometimes suggested that an action of the after-effect upon a connection is impossible because the connection, being past and gone, is inaccessible. This is too extreme. As was stated in the previous chapter, the physiological equivalent of a connection does not thus vanish utterly in the twinkling of an eye. Whatever it is, it is there a second after it occurred in a manner or degree quite different from that of a connection of an hour ago. Experiments of Roberts ['30] have proved that delay in applying a reward weakens its effect. That a reward delayed for

* The important contributions of Franz, Lashley, and others do not, I think, negative localization in general, but rather certain narrow and inadequate views of behavior and learning.

† The reader interested in the anatomy and physiology of learning may examine the hypotheses of Thorndike ['13, pp. 222-228], Johnson ['27], and Troland ['28, pp. 202-226], and the ingenious machines which modify their own behavior devised by Stephens ['29] and Hull and Baernstein ['29].

five seconds does less than one applied after one second implies that the inaccessibility develops with time. The very fact that the reward belongs with the connection implies that something equivalent to or related to the latter persists and is accessible in some manner to the influence of the reward.

Moreover, are we not in a worse difficulty if we replace the direct action of the reward itself by an indirect action through a representation of it? If the satisfaction following $S \longrightarrow R$ does nothing when it occurs, but an image of the satisfaction strengthens the connection later, we have either back action upon something left by the actual occurrence of the connection across a much longer interval of time since $S \longrightarrow R$ occurred, or we have a recurrence of the actual situation (S) arousing inner representations (Ri) of the former response and (Ai) of the satisfying after-effect, and have Ai strengthening $S \longrightarrow Ri$, which then somehow causes a strengthening of $S \longrightarrow R$. It is always $S \longrightarrow R$ which must be strengthened, and it is strengthened *ex post facto via* something left by it just as truly if the strengthening is indirect by an Ai as if the strengthening is direct by an A.

Much has been made of the difficulty a reward must have in attaching itself to the connection producing it rather than to other connections as near or nearer to the reward in time. Such difficulties are real, and rewards will be effective only in proportion as the *right* connection is close to the reward in time or in belonging, or in both, but a process need not be infallible to be effective in learning. The "errors" of attachment of the reward, as when a cat that has learned to manipulate contrivances so as to escape from puzzle-boxes by a food reward will whisk in and out of the open door, are just what should be expected.*

It is worth while to consider what the reward *seems* to do

* It should be noted that even if "belonging" played no part and the reward strengthened all preceding connections in some relation to their proximity, rewards would still favor learning the "right" connection, since it, as compared with any one "wrong" connection, will be closer in time to the reward.

to the connection. It seems to accept it, say "Yes" or "O. K." to it, endue it with acceptability. Human learners can observe this in themselves. If the situation is easily identifiable and if the response is easily available or summonable, and if there is time, this acceptance often leads to an actual repetition of the connection or some ideational equivalent of it, as when the teacher's *Right* after *calamary* → *squid* makes the learner say it over again to himself.

It is conceivable that this acceptance, tolerance or "O. K." reaction is very fundamental and universal in the animal kingdom, and that its physiological equivalent strengthens any connection to which it is attached. Thus there would be a simple unitary process through which all the wide variety of satisfying after-effects (foods, praise, encouragement, free exercise of cherished activities, and the like) could operate upon the still wider variety of connections producing them. This hypothesis would also account admirably for the potency of symbolic satisfiers such as *Right, Score 10* or *Your point* which can cause the "O. K." reaction as easily as the richer and more vivid satisfiers.

In this connection, as well as for many other reasons, we need experiments in which variations in the intensity of the satisfyingness of the after-effect are studied in relation to learning. If increases in intensity above a certain moderate amount have no effect, the hypothesis of the "O. K." reaction would be more attractive.

Whether satisfying after-effects strengthen the connections which produce them directly, or *via* an "O. K." reaction, or in some other way, the question remains of the physiological method or process by which the strengthening is caused. Does the rewarded connection last longer? Is it kept freer from disturbance?

That a connection lasts longer may mean that some feature or consequence of the action in the neurones of the brain, which is its physiological counterpart, lasts longer when it is followed by a satisfier than when it is followed

by an annoyer. This might well be true; and could happen in those acts of motor skill, such as actual performance at tennis or typing or playing the violin, where there is no conscious repetition or prolongation of the connection.

A beginner at tennis, for example, returns the ball over the net into the court and is satisfied thereby. The game goes on and there is no conscious repetition or prolongation of the situation and response together, but some feature or consequence of the action in the brain which caused the linkage of the latter to the former may conceivably last longer in such a case than in a case where the learner responded to the same situation by popping the ball feebly into the net.

This hypothesis is then conceivable and has the merit of being simple. Call the physiological counterpart of a connection C; call the predisposition left by it C_p. Then, other things being equal, if C takes place four times for a half-second each time, it leaves a greater or stronger C_p than if it occurs once. If C takes place for two seconds it presumably would leave a greater or stronger C_p than if it lasted only a half-second. Frequency strengthens a connection by adding more C's at intervals. The influence of a sequent satisfier is neither more nor less mysterious than that of a repetition.

Here we have something which is subject to observation and experiment. If satisfying after-effects operate by maintaining C for a longer time, maintaining it for a longer time by causes other than satisfying after-effects should strengthen it.

§ 1. Experiments on the Influence of the Time Following the Action of a Connection Before its Situation is Responded to Again

Experiment 81

Experiment 81 was designed to test the influence of the time intervening after the appearance of the situation and

of a proper response to it until the individual responds again to the situation or a competing situation. Will that connection, which has a long interval of this sort after it, be strengthened more than a connection in other respects like it, but with a shorter interval? The experiment was as follows:

A series of 5x8 cards was prepared, on the front and back of which were printed two statements of equal interest and importance to the subjects concerned, but varying greatly in length. Both of these statements were printed on the lower half of the card. A cardboard flap was then arranged over one of these statements. The total series consisted of 38 such cards. In 19 of them the statement under the flap was long and the statement on the back of the card was short. In the other 19 the statement under the flap was short and the statement on the back of the card was long. On the whole the long statements were about four times as long as the short (30 inches to 7½ inches of typewriting).

The subject took the series of cards and used them under the guise of a learning experiment. He expected to be tested later in respect to how many of the facts he had learned. He was instructed to go through these 38 cards as follows: "Take the card; lift the flap; read what is said beneath it; put down the flap; turn the card over; read what it says there; put the card aside; take the next card and continue." These instructions were faithfully performed, the work being done under a certain amount of supervision and by students who had no motive to depart from the instructions at all. Observations showed that, in point of fact, the time spent on the longer side of the card was very much greater than the amount of time spent on the short side.

The cards were of two sorts. Those which had the long statement on the front under the flap, had the flap held by pasters of blue in whole or in part. The other cards, which had the long statement on the back, had their flaps held entirely by pasters of white.

There are thus two situations, cards with blue pasters and cards with white. There are two responses, lifting flap and turning card. The attention given to the four sorts of connections is presumably equal, and the length of the connection as a conscious matter is presumably equal in all four, but in two the underlying C's are soon followed by their alternatives, whereas in the other two they may last much longer.

The interval after lifting a card with blue pasters or turning a card with white pasters was about four or five seconds. The interval after lifting a card with white pasters or turning a card with a blue paster was about a second.

After the subjects had gone through the series from 10 to 20 times, they were tested as follows: "You will now go through the cards as before except that at this occasion you may either lift the flap and read what is underneath, or you may turn the card and read what is on the back. You must not do both. With any card you may do either one that you happen to feel like doing."

The experimenter kept track of the reactions as lifted whites, lifted blues, turned whites, or turned blues. The results for 21 subjects were as follows: 396 for lifted blues and turned whites, and 402 for lifted whites and turned blues.

Experiment 82

A similar experiment was carried out with ten other subjects, each of whom lifted and turned 38 cards four times and then were tested. The lifted blues and turned whites numbered 208 in this case to 172 lifted whites and turned blues.

Experiment 83

A similar experiment was carried out with twenty-one other subjects, each of whom lifted and turned the 38 cards seven to eleven times and was then tested. He then lifted

and turned them three to five times more and was tested again. The lifted blues and turned whites numbered 398 to 400 lifted whites and turned blues in the first test, and 393 to 405 in the second.

On the whole, the connections followed by responses after the long interval are favored to the extent of 1395 to 1381. On the whole, there is thus 1% excess operation in the test of the connections followed by the longer interval in the training, but this is a very unreliable determination, resting entirely on the group of ten subjects with a relatively small amount of practice. The forty-two subjects with extended training showed a reverse effect.

The weak point of this experiment is that the differential feature of the situations, the blueness of pasters on some, may not have been connected with anything. The lifting or turning may have belonged only to a card. The blueness was, however, a conspicuous part of the external situation. It was not permissible to direct the subjects' attention to it, since that might have made them aware of the construction of the set of cards.

I have not found in the literature of learning and memory any results showing the effect of leaving the underlying physiological C undisturbed for varying time intervals, with attentiveness, and length of the connections as conscious facts equalized, such as might be added in along with those of Experiments 81, 82, and 83. The results on the distribution of practice in general are not suitable for our purpose, since they concern long intervals (of a minute or more) between practice periods in each of which a multitude of varying connections are practiced. Experiments in which series of elements to be memorized are presented at varying rates are not suitable, since the intervals that are varied in these are between the two terms of a connection, not between the activity of one connection and that of another.

§ 2. Experiments on the influence of disturbance of the underlying physiological process

In the long run, connections productive of satisfying states of affairs are less likely to be checked, set aside or interfered with than connections productive of annoyance. Is the gain in strength of the underlying C and of C_p, the predisposition left by it, perhaps due to its relative freedom from disturbance by other activities in the brain?

As an experiment to gain some light on this we have tried to measure the gains in strength of two connections, alike save that one of them led on to, and was in a sense a step toward, further activity, whereas the second was more final. One was in a sense displaced by later activity, while the other was undisturbed. Just what the introductoriness and finality were, and how far there was a greater freedom from disturbance the reader may decide from the description of the experiment (84).

Experiment 84

In Experiment 84, the subject studied a set of 60 cards like the 38 used in Experiments 81-83, except that the cards were of three colors, the flaps were white, black, or blue, and the statements were of equal average length whether under the flaps or on the backs of the cards. The statements also varied in interest and value, but the average interest and value was the same for those under the flaps and those on the backs. Color of card, color of flap, and interest of statement were all camouflage, arranged to distract attention from the main purpose of the experiment which was simply to ascertain whether the *last thing done* to a card (i.e., turning) would be favored when, after three rounds of the series, reading both statements in preparation for a memory test, the subject was told to go through the series either lifting the flap or turning the card.

For the general training the following instructions were given:

> You have here 60 cards with a flap on the front of each. There is something printed or written under the flap and also on the back of the card. You are to take the top card; raise the flap and read out loud at your ordinary rate what is printed under the flap. Then turn the card over and read at your ordinary rate what is printed on the back. Do the same with the second card, the third, the fourth, and so on. You will later be tested as to your memory of what you have read, but do not read slowly on this account and do not make any strain to give careful attention.

The instructions for the test series were:

> This time you will read as before, except when you take up each card you will either lift the flap and read what is under the flap, or you will turn the card over and read what is on the back. You may lift the flap or turn the card in any case, just as you happen to feel like doing.

We may argue that when the subject lifts the flap of the card he has to be set to turn the card later, but that when he turns it his brain is freer from suspense as regards that card (though he does have to be set toward laying it down preparatory to taking another card). At least we may claim that if there is any difference in respect of freedom from disturbance of the physiological basis of the connection it is in favor of *holding card*→*turn it* rather than *holding card*→*lift its flap.*

So we compare the percentages of lifts and turns after the training with that of a control group lacking the training. For eighteen individuals having the training, there were 51% of lifts and 49% of turns (554 and 526 out of 1080). For the control group of forty-three individuals, who went through the series once, lifting the flap or turning the card as they pleased, the corresponding percents were 59 and 41.* The training thus seems to have strengthened

* The experiment is faulty in that the turns in the training were responses to the situation "holding a card whose flap has been lifted and whose statement thereunder has been read," not to "holding a card just taken up from the pile." We should therefore expect the training, by the force of frequency alone, to strengthen the tendency to lift the flap of a card when taken up from the pile, but how much it would do so we do not know. Further analysis by additional experiments is required. Allowance for this influence by fre-

the *hold card*$\rightarrow$*turn it* connection at the expense of the other.

Experiment 85

A better experiment to measure the difference between connections left relatively undisturbed for a short time and connections somewhat interfered with was performed by Dr. Lorge. The instructions were:

In this experiment you are to do two tasks: Complete sentences; cross out letters.

1. Each sentence is to be completed with one word that will make the whole sentence true and sensible; for example,
   Columbus in 1492 discovered........................
   would be completed with America as
   Columbus in 1492 discovered America.
2. In each line of letters you are to strike out each A, for example
   KACE LAKB EHOH LHAE BHOB EACB
   would have every A crossed out as
   K~~A~~CE L~~A~~KB EHOH LH~~A~~E BHOB E~~A~~CB

Do the work on each page in the order that it is presented. Complete each sentence. Work as fast as is possible consistent with accuracy.

If you finish before time is called, bring your paper to the experimenter.

The material consisted of 160 completions like those of the sample below and 160 lines of capital letters like those shown below. Half the subjects had one line of capitals after each completion. The other half had either 20 completions, 20 lines to check, 20 completions, 20 lines to check, and so on, or 20 lines to check, 20 completions, 20 lines to check, 20 completions, and so on.

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quency alone would decrease the 49% at the expense of the 51%, and so strengthen the evidence that the factor of freedom from disturbance had a positive potency.

1. The barbarian invasions destroyed the economic life of the Roman ....
2. CAEH BCKL BEAH LACH BEHC AKBE
3. The Rule of St. Benedict enjoined daily manual labor upon the ....
4. EHAK LKAB HCLE BCHB CAEH CBAE
5. In the 17th century England and Holland were the chief claimants for commercial ....
6. HBKA CHBL ACCL ABCE HBEA ECKH
7. The breaking up of large estates in 1789 and the laws of equal inheritance have made France a country of small ....
8. KACE LAKB EHCH LHAE BHCB EACB
9. The move toward industrial combination was a natural result of unrestricted free ....
10. CEBH AKBL KEAH CBEH ACAL BCHE

On the average, about 166 units of each sort were completed within the time allotted (30 minutes for all subjects). (The averages under the 1, 1 arrangement were 67.3 completions and 67.2 lines of letters; the averages for the 20, 20 arrangement were 66.2 completions and 65.2 lines of letters.)

At the end of the allotted time, the papers were collected and a memory test of the sentences which had just been read and completed was given. This test consisted of sentences 1, 3, 5, 7, 9, etc., of the first 80 of the 160 sentences, each with four words omitted, as shown below for sentences 1, 3, 5, 7 . . . 15. Fifteen minutes were allowed for this test.

1. The .... invasions .... the .... life of the .... empire.
3. The Rule of St. .... daily .... upon the monks.
5. In the .... century England and .... were the chief .... for .... supremacy.
7. The breaking up of large .... in 1789 and the laws of equal .... have made .... a country of .... farms.
9. The move toward .... combination was a natural .... of .... competition.

11. In .... most .... belonged to the .... of England.
13. During the .... period close .... relations existed between .... and the West Indies.
15. The chief .... between .... and .... civilization were in Spain, in Sicily, and in the Near East.

The subjects of the experiment had no knowledge that any such memory test would be given. Consequently the test measures the strength of the connections formed by reading the sentences sufficiently to complete them, not by reading them with a view to remembering them.

In the 20, 20 arrangement the reading of each sentence (except the 20th) is immediately followed by another, whereas in the 1, 1 arrangement the connections formed by reading a sentence are, perhaps, left relatively undisturbed while the subject performs the routine task of checking the numbers. In so far as we can assume that they are, the memory scores for the two random groups will inform us about the effect of relative freedom from interference.

The results appear in Table 124. There is only a very slight and unreliable advantage (about 1.2%) for the 1, 1 arrangement. There is about one chance in three that further experiments with many groups would show zero advantage or harm, and about one chance in a hundred that they would show an advantage as great as 8%.

TABLE 124

THE EFFECT OF INTERPOLATING, AFTER EACH UNIT OF COMPLETIONS, 1 UNIT OF CHECKING NUMBERS, CONTRASTED WITH THE EFFECT OF INTERPOLATING, AFTER EACH 20 UNITS OF COMPLETIONS, 20 UNITS OF CHECKING NUMBERS

N	Group	Mean Score Odd	Mean Score Even	Mean Score* Total
47	I (unit A, unit B, etc.)	38.83	40.27	79.10
23	II (20 units A, 20 units B, etc.)	39 03	37.75	76.78
24	III (20 units B, 20 units A, etc.)	40.10	39.41	79.51
	Average of II and III	39.57	38.58	78.15
	I minus Av. of II and III	−0.74	+1.69	+.95

* The score is the number of words correctly completed in the test. Fractional values were given for synonyms approximating the correct response.
Task A = Completing sentences. Task B = Crossing out letters

We need to make more ingenious experiments in which the probability of persistence and freedom from disturbance of the underlying physiological processes is greater. We need also, and especially, to learn whether the action of satisfiers is general, uniform, and inevitable, and consequently likely to be due to any single and simple sort of physiological activity. There may be many intensities and specializations ranging from a mild acceptability to the fulfillment of a craving which absorbs the mind, and from sensory pleasures like eating when hungry to symbolic satisfiers like reaching the place where food may be expected.

We need also to know more about the physiology of connections, strength of connections, satisfiers, and the other forms of strengthening by repetitions with neutral, or even mildly annoying, after-effects.

We may close this inconclusive chapter by a statement of what the events are whose physiological basis is sought. This statement goes somewhat farther than the facts of Chapters IX, X, and XI warrant, but has the merit of being clearer and more emphatic than the statements so far made.

The chief force modifying a connection is the state of the organism for the second or so just *after* the connection has operated. The repetition of a connection indeed has its main potency as an opportunity for this state of the organism, the after-effect as we have called it, to exert its influence. Its influence, provided the situation remains, is sometimes to set up a different response to the situation, and sometimes to cause the animal to continue or repeat the response just made. If the situation vanishes, a state of the organism which would have caused the animal to continue or repeat the response just made, had the situation remained, causes the animal to be more likely to make that response if the situation recurs. In both cases it presumably strengthens the connection then and there. This strengthening causes continuance or repetition of the response then and there if the situation persists, and an increased proba-

bility of repetition later whether the situation persists or not. If the situation vanishes, a state of the organism which would have caused the animal to set up a different response to the situation, had the situation remained, does not so uniformly cause the animal to be more likely to make that different response if the situation recurs. The brain may be able to strengthen a connection without actually continuing or repeating its operation, but not to strengthen some connection other than it save by getting this other connection or some part of it into actual operation. This difference is reasonable since in the former case the connection to be strengthened has just been active and its trace is there, whereas in the latter case no such trace is present. The experiments of Chapter XI make it highly probable. But it should be subjected to further experiments.

CHAPTER XIII

Readiness, Identifiability, and Availability

This chapter will report three very important sets of facts very briefly.

§ 1. Readiness

Two connections, $S_1 \longrightarrow R_1$ and $S_2 \longrightarrow R_2$, may be of equal strength in the sense that the probability that S_1 will evoke R_1 is equal to the probability that S_2 will evoke R_2 in general, but on any particular occasion $S_1 \longrightarrow R_1$ may be much more likely to operate than $S_2 \longrightarrow R_2$. Such may be the case as the result of the repeated action of $S_2 \longrightarrow R_2$ without rest, or as a result of some sort of preparation of $S_1 \longrightarrow R_1$ by the set or adjustment of the mind, or because $S_2 \longrightarrow R_2$ is in refractory period, or because R_1 and R_2 are in chronic states of readiness and unreadiness, respectively.

To account for such facts, we need to assume a quality in responses and connections, which may be termed excitability or readiness to act. Low or negative status in respect to it may be called refractoriness or unreadiness.

Responses may differ one from another in their readiness to act. Eating has, by and large, a much higher degree of readiness than vomiting; laughing, than hiccuping; looking at bright moving objects, than hiding one's face in one's hands. The same response varies from time to time in readiness. Hunger adds to the readiness to eat; weariness subtracts from the readiness to play and augments the readiness to sleep. Behavior and learning are influenced by the readiness or unreadiness of responses as well as by their strength.

Roughly speaking the strength of connections determines what a mind can do, but what it will do depends upon not

only the strength but the readiness of each. A connection may be strong and ready, strong but unready, weak but ready, weak and unready. The actual probability that a given S will evoke a given R on any occasion depends upon its readiness then as well as on its strength.

We have made no special experiments upon readiness and have little to add to what was written about it many years ago [Thorndike, '13, pp. 125-133]. Learning may consist in changing the readiness of connections as truly as in changing their strength. The stimulus which at first evoked only a certain narrow action of responses A and B, may later make C, D, and E readier to act. We have, in every case, the problem of deciding what connections and responses are made ready or unready by any experience whose influence upon learning we are to describe.

We may record here two minor observations made in the course of our studies of the repeated action of the same situation, and a summary of the very interesting results obtained by Zeigarnik ['27].

In Experiments 25 and 26 in which the subjects wrote spellings for nonsense words, there was some evidence of a tendency within a sitting to *decrease* the frequency of the initially most frequent response. Thus the records of *s* for the hissing s sound, *o* for the long o sound, and *a* for the long a sound (as in *late*) were as follows for the successive fifths or fourths of the first sitting and for the first two-thirds of the second sitting.

	First Sitting					Second Sitting	
	1	2	3	4	5	1	2
s	777	785	710	719	712	798	796
o	703	672	723	677		709	687
a	594	463	462	537	389	573	413
Sum	2074	1920	1895	1933		2080	1896

Apparently the mind loses its readiness to write *s*, *o* and *a*, but regains it after the interval. For the sounds of *e*, as in *delete*, *ou* as in *house*, and *aw* as in *lawn*, a much greater decrease in the frequency occurs and a larger part

of it carries over to the second sitting. This part is perhaps due to favoring the simpler or less ambiguous spellings, especially of the *ou* and *aw* sounds.

	First Sitting					Second Sitting	
	1	2	3	4	5	1	2
e	496	387	437	435	355	474	397
ou	448	238	243	286		238	289
aw	422	247	264	276		312	222
Sum	1366	872	944	997		1024	908

We quote here, a report of similar results with numbers. "In one of our experiments, six subjects wrote a number (from 0 to 9) whenever they heard a word. 3840 words were read, 320 at a sitting, including 60 occurrences of each of two words, and 40 occurrences of each of ten others, and from one to ten occurrences of several hundred other words. The experiment was designed as one of many to throw light on the influence of repetition. This purpose was somewhat masked by presenting the experiment as one on 'thought-transference and other problems.' The subjects were told that when the experimenter read a word he would think of some number from 0 to 9, and that they should write the first of these numbers that came to their minds, and that in any event they should write some number from 0 to 9 for each word by the time the next word was spoken. The words were read at the approximate rate of one every 2½ seconds. They were thus left free to write numbers from 0 to 9 in a perfectly chance order. The maximum interval from the beginning of writing one to the beginning of writing the next would be about 4 seconds; the minimum about ½ second (in cases where the number for the preceding word was not written until the next word was begun). The oft-repeated words still came only rarely compared with the total number, and there was no statement or hint that the experimenter would always think of the same digit for the same word. The subjects did not in fact come to form stable associations with the repeated words, save very rarely, within the first 2560 responses

(which are all that are used here). It would have made very little difference if they had.

"By chance there should be at least ten percent of sequences like 00, 11, 22, 33, 44, etc. There would in fact be more than ten percent, since all the subjects had more or less favored numbers. The number of sequences (00, 11, 22, etc.) is far below this in five of the six subjects, and slightly below it in the other, being as follows:

	C	M	P	R	S	W	Total
Day 1—First 320 responses	23	22	6	17	12	50	130
Second 320 responses	10	12	18	13	11	35	99
Day 2—Third 320 responses	7	13	21	9	13	22	85
Fourth 320 responses	7	5	6	8	12	48	86
First 1280 responses	47	52	51	47	48	155	
% in 1st 1280	3.7	4.1	4.0	3.7	3.8	12.1	
Day 3—Fifth 320 responses	17	3	6	7	8	22	63
Sixth 320 responses	22	14	6	12	12	32	98
Day 4—Seventh 320 responses	5	5	12	13	9	14	58
Eighth 320 responses	8	0	10	9	7	10	44
Second 1280 responses	52	22	34	41	36	78	
% in 2d 1280	4.1	1.6	2.7	3.2	2.8	6.1	

"The increasing avoidance of sequences from sitting to sitting and day to day is noteworthy.

"In a somewhat similar experiment where numbers from 1 to 9 were written, under the same time conditions, the following results were obtained, all in one sitting:

NUMBER OF SEQUENCES OF 11, 22, 33, ETC.

	A	B	C	D	E	F	G	H	Total
First 320	10	0	8	19	7	27	5	10	86
Second 320	4	1	8	14	5	31	19	9	91
Third 320	8	1	21	15	7	17	21	8	98
Entire 960	22	2	37	48	19	75	45	27	
% in 960	2.3	0.2	3.9	5.0	2.0	7.8	4.7	2.8	

Chance should give 11.1 percent as a maximum, since there were only nine digits used and there was considerable favoritism in numbers.

"In an experiment of the same general nature,* but with

* Hundreds of nonsense syllables were read and the first number of the numbers 0 to 9 which came to mind was to be written after each. The reading had been preceded by a presentation in which forty of the nonsense syllables had been connected, each with certain numbers.

a time interval of 5 seconds between the reading of the words (nonsense syllables in this case), the avoidance of sequences is not nearly so great as in the experiments with the $2\frac{1}{2}$ seconds interval. The facts for eight subjects for the first 640 responses are as follows:

	F	G	H	K	M	Wag	Wa	Wi	Total
First 320 responses	23	5	23	16	31	21	32	6	157
Second 320 responses	59	33	27	24	46	29	39	7	264

These results with numbers were reported earlier (*Psychological Review,* Vol. 34, pp. 234-236). Professor Raymond Dodge commented upon the facts as follows:

NOTE ON PROFESSOR THORNDIKE'S EXPERIMENT

"The foregoing report by Professor Thorndike represents an exploratory but direct experimental attack on the problem of the influence of the refractory phase on free association. The general question might be stated as follows: Does the associative process furnish any evidence of a barrier against immediate repetition that can be identified with refractory phase? Taken by themselves the experimental results give a quantitative indication of some tendency of the subjects to distribute associations and consequent responses within the limits of an arbitrarily limited system. Thorndike raised the question of the nature of this tendency, but did not subject it to experimental analysis.

"Several plausible hypotheses occur to one to account for the experimental results. In the first place, it is possible that the subjects developed a conscious or unconscious bias in favor of the distribution of their associative response. This might easily have arisen in some of the subjects as a reasonable interpretation of the instructions. But assuming that it was a chance interpretation of instructions which themselves gave no real clues, it would be surprising if the same bias developed unanimously in all subjects unless there existed some fundamental tendency toward that par-

ticular bias. In the second place, the general tendency of the subjects to distribute their responses might represent a habit of the group. It probably does. But if that habit is a casual result of experience and training, one would expect some exceptions in a group of even moderate size. Its unanimity and consistency suggest some underlying tendency to account for it. Thus, in whatever way they are viewed, Professor Thorndike's experiments seem to me to point to the operation of some general or common barrier against immediate repetition, but hypotheses as to the nature of that barrier including the supposition of a refractory phase rest on other grounds.

"It is not difficult to imagine a crucial extension of Professor Thorndike's experiment. If various time intervals between stimuli could be used, a suppositious refractory phase in the barrier against repetition should theoretically be more apparent the nearer the responses approach each other in time. Conversely, the longer the time interval between responses the less such a barrier should operate. Furthermore, if the tendency is really due to refractory phase, one would expect, other things being equal, a critical frequency at which the tendency to repetition would be equal to expectation by chance, and a subsequent period of rebound during which the tendency to repeat would be exaggerated.

"Something like this sequence appears in various cases of free association and constructive imagination, where experimentally induced bias is precluded and where the satisfaction of the reactor is the principal determinant.

"In good writing, for example, there is a marked reluctance to repeat sounds, words, phrases, or paragraphs. This does not represent an absolute barrier, but a relative reluctance decreasing with time. Repetitions of the same word or phrase may be close enough together to reinforce each other, apparently constituting a single stimulus. A little farther apart they tend to annoy and disturb the reader. Still further separation may render the repetition

entirely satisfactory. Under certain circumstances even paragraphs may be repeated without serious offense, as in the summary of a paper. A sequence corresponding to refractory phase and the rebound is even clearer in some works of art where the play of association and constructive imagination is determined more exclusively by its satisfactoriness. In poetry, for example, rhythm, rhyme, and the repetitions of sounds and phrases with slight modification are illustrations of the point. Here again repetitions may be close enough to reinforce one another. Such reinforcement may under favorable circumstances reach a kind of ecstasy, as in the beating of drums and in negro spirituals. The evolution of melodic themes indicates some barrier against simple repetition within rather definite intervals. The repetition of musical phrases in many forms of music at longer intervals and the repetitions that are permissible in choruses all look in the direction of increased readiness to respond.

"Probably all artistic composition is a kind of free association governed fundamentally by the satisfactoriness of the productive activity or the art products. Even artistic sophistication and tradition doubtless start there. Time measurement of these reinforcements, barriers, and predispositions to repetition in writing and music is entirely feasible. It would seem to be another practicable avenue of approach to a scientific evaluation of the influence of refractory phase in free association. Doubtless something similar also appears in other forms of art, as in the recurrence of motifs in decorative art and architecture.

"The operation of all such barriers and predisposition to repetition is probably complicated by the complexity or refinement of organization of the systems in which they appear. In some primitive or relatively less developed systems the refractory phase is apparently shorter than it is in more developed and more complex systems. There is some evidence of this in the reactions of children and infrahuman species. Refractory phase may also be very short

in certain dementias, which are characterized by stereotypy. High intellectual development seems to increase the barrier against repetition. At present all this is mere conjecture. What we need is quantitative data as to the facts. Apparent evidence of the influence of refractory phase and rebound is found also in the distribution of optimal repetitions in the learning process. This again may differ in children from what it is in adults. Finally, the barrier to repetition may vary apparently within the individual's experience, as the process becomes relatively automatic. Robinson and Bills* found that rapid repetition of homogeneous responses succeeded best without full attention, while the subject carried on concurrent daydreams. This looks to me like an experimental verification of the advantage of simple forms of mental organization. Perhaps the agreeableness of the daydreams was not insignificant.

"There are some grounds in everyday experiences for supposing that an effective reinforcement of either the perseveration tendency or its barrier is possible. The effects of prizes and rewards on the one hand and punishment on the other look like something of this sort. Something similar seems to appear in the emotional reinforcement of mental stereotypy in worry, and the unrational repetitions of behavior in other emotional states.

"The concomitance between effective experience and readiness to respond has been given theoretical significance by Thorndike himself in his hypothesis of the nature of feeling. The theory has never received the experimental verification that it seems to me to deserve. I have no new grounds for identifying the two phenomena, but some close relationship seems to me highly probable on the basis of common experience.

"As I have elsewhere pointed out, if the principle of refractory phase does not apply to mental life, there is something so similar to it that it is at present indistinguishable

* Robinson, E. S., and Bills, A. G., "Two Factors in the Work Decrement," (*Journal of Experimental Psychology*, 1926, Vol. 9, 415-443).

from it. If physiologists had not discovered the principle, psychologists would have had to postulate it to account for the control of the perseveration tendency. Unless recency of human reaction involved some agency that operated to delay repetition, the perseveration tendency would tend to make us live out our lives on the low level of stereotypy within the limits of relative fatigue or exhaustion. One conjectures not only that this barrier against repetition plays an important rôle in the common desire of humanity for variety and new experiences and in the evolution of art, but also that it is somehow involved in the very foundations of science as a condition of the tendency of specific human experiences to undergo systematization and generalization. It may thus have been an important factor in the development of science as well as art.''*

Zeigarnik ['27] working under Lewin's direction found that if a person is given, one after another, a score of things to do, and is forced or led by the experimenter to stop and leave unfinished half of them, and is at the end of the period directed, ''Please say what things you have done during the experiment,'' he reports a much larger percent of the interrupted tasks than of the completed tasks. The median ratio of $\frac{\text{Percent of interrupted which are remembered}}{\text{Percent of completed which are remembered}}$ was 1.55 in Experiment I, 2.15 in Experiment Ia, 1.7 in Experiment II, and 1.7 in Experiment IIa. The corresponding averages of the ratios (which Zeigarnik uses) are 1.9, 2.0, 1.9, and 2.1.†

When certain of the tasks are interrupted as above, while the others are interrupted but later completed, those interrupted are much better remembered than those interrupted but later completed. The ratio:

* *Psychological Review*, Vol. 34, pp. 237-240.

† These and later ratios are computed from the lists given fluently. Memories resulting from extended search after a period of hesitation are excluded. Their inclusion would lower the ratios a little.

$$\frac{\text{Percent of interrupted which are remembered}}{\text{Percent of interrupted, but later completed, which are remembered}}$$

is closely the same as the ratio

$$\frac{\text{Percent of interrupted which are remembered}}{\text{Percent of completed which are remembered}}.$$

The median for the twelve subjects concerned were 2.0 and 2.25; the averages were both 1.9.

Whether the experimenter says, when he interrupts a task, "Now do this (naming the next task); the interrupted task we will complete later," or whether, on the contrary, he says, "That will be enough! You will not carry that task any further," makes no difference in the ratios for memory.

The memory ratio $\frac{\text{interrupted}}{\text{completed}}$ for interesting tasks was not higher than 1. That is, the subjects remembered the tasks which they were interested in as well when they completed them as when they were prevented from completing them.

If the whole list of tasks which a person is to perform is read to him before he begins them, the ratio $\frac{\text{interrupted}}{\text{completed}}$ is not higher than 1.

Ten persons had been tested who had been busy at mental work for six or seven hours and reported themselves as fatigued. For these $\frac{\text{interrupted}}{\text{completed}}$ is below 1, averaging .74 (median .75).

In six persons who were excited (*aufgeregt*) the ratios averaged .78 (median .80). In eleven persons whose memories were measured the day after the experiment the ratios averaged 1.14 (median 1.2). In six persons who were *durchgeschüttelt* at the close of the experiment, as by an unexpected telephone-call or personal discussion, the ratio was only .64.

These observations support, though somewhat feebly, our hypothesis that every connection has at any given time not only a certain strength but also a certain readiness. The main supports for it, of course, are the facts of the refractory period in reflexes, of fatigue and neurasthenia, and of the varying excitability of original and acquired tendencies or drives. Psychologists have not denied it; they have merely neglected it. It is too important to neglect. In

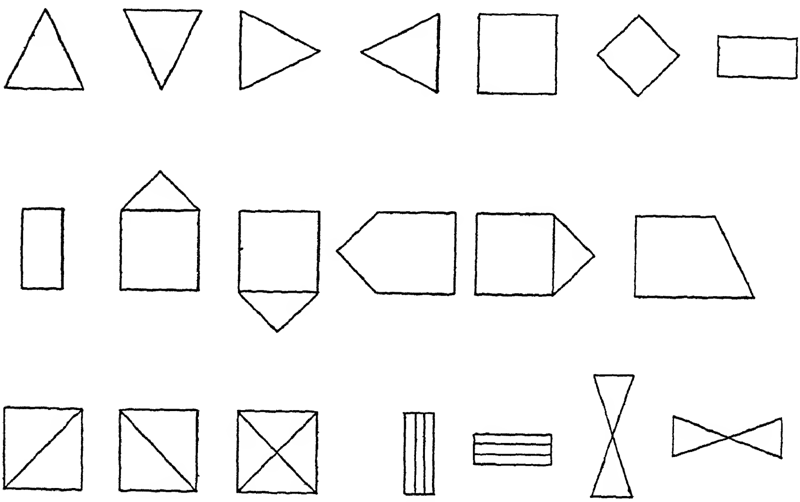

FIGURE 7.

every act of learning the readiness of the connections concerned is a conditioning factor; and in the learning of interests, attitudes, and motives readinesses are a large fraction of what we learn.

§ 2. IDENTIFIABILITY

"Consider these two acts of learning: first, to connect each of the twenty shapes shown in Figure 7 with a number from 1 to 20; second, to connect each of the twenty shapes shown in Figure 8 with a number from 101 to 120, so that in each case the person, knowing that a shape is one of the given twenty and is to be responded to by one of the

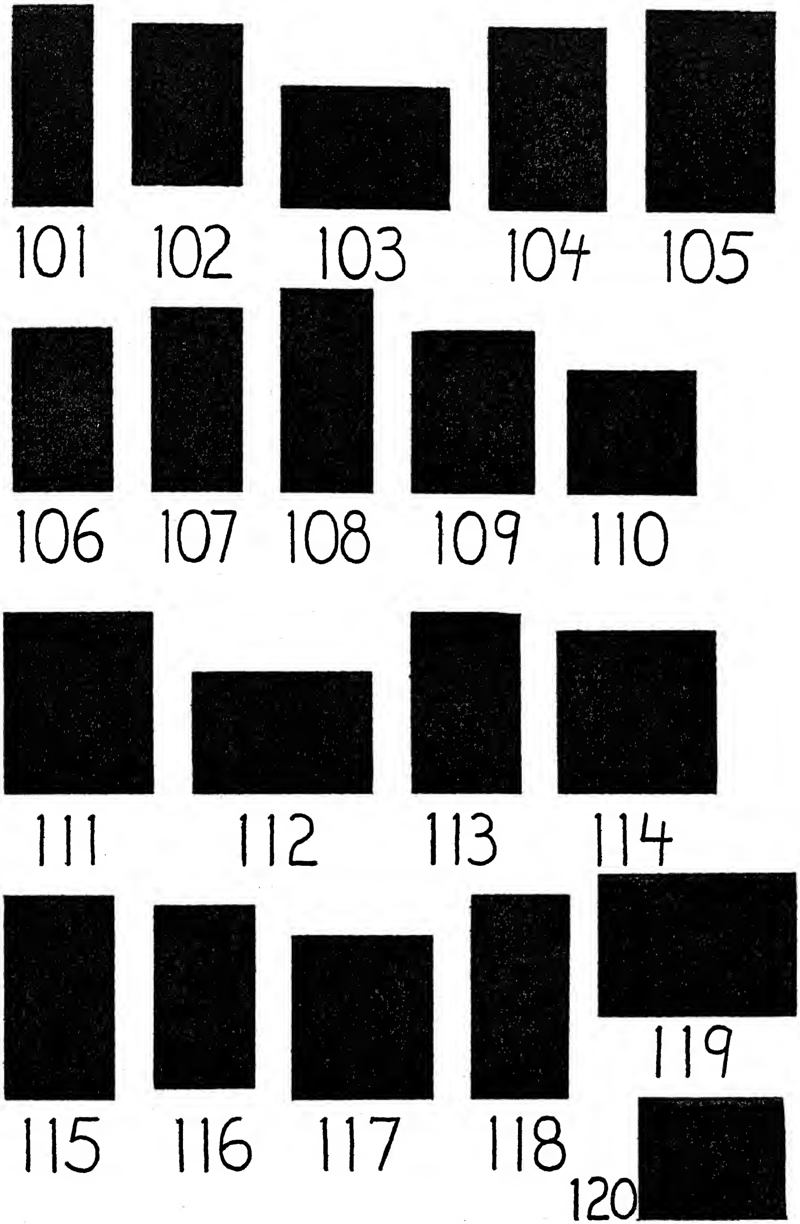
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FIGURE 8.

given numbers, can tell which number belongs to it. The former learning is easy. If a person is led to say the right number for each a score of times with awareness of the belonging together of each shape and number and with a moderate amount of acceptability attached to the question, he will know many, perhaps all. Or if he is required to guess, his guesses being followed by *Right* or *Wrong*, he will make sure progress and master all or nearly all of the connections in from twenty to thirty trials.

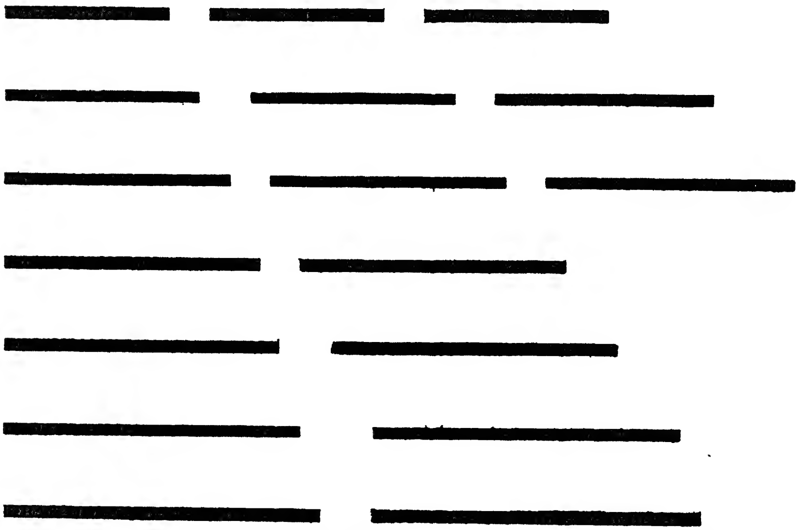


FIGURE 9. Reduced in linear dimensions to approximately one-fourth.

"The latter learning is hard. Progress is slow and mastery probably will not be attained in a hundred repetitions of the right connections, or guesses with the announcement of *Right* or *Wrong*.

"Six educated adults were trained with a series consisting of such strips as shown in Figure 9 plus others, the entire series containing strips of 3½, 3¾, 4, 4¼, and so on to 11, 11¼, 11½, 11¾, and 12 inches. Each subject responded not by a number from 1 to 20, but by saying 3¼, 3½, 3¾, 4, 4¼, 4½, 4¾, etc., which presumably made the learning somewhat easier. A strip was laid before him on a green

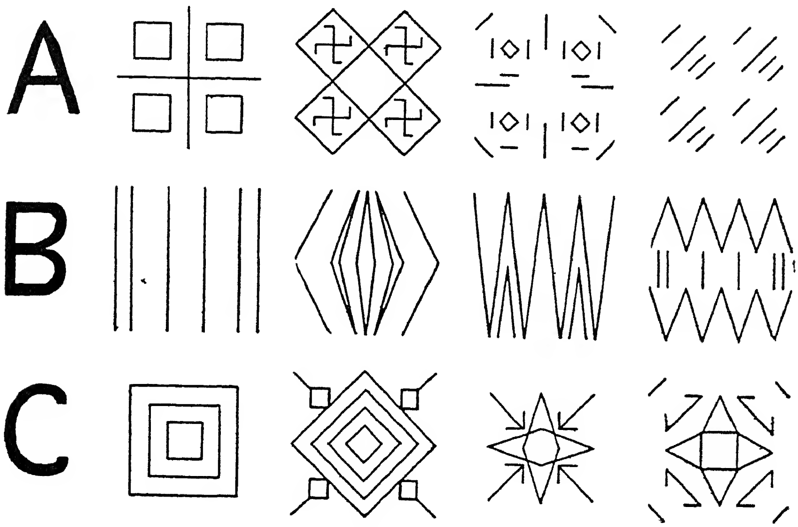


FIGURE 10.

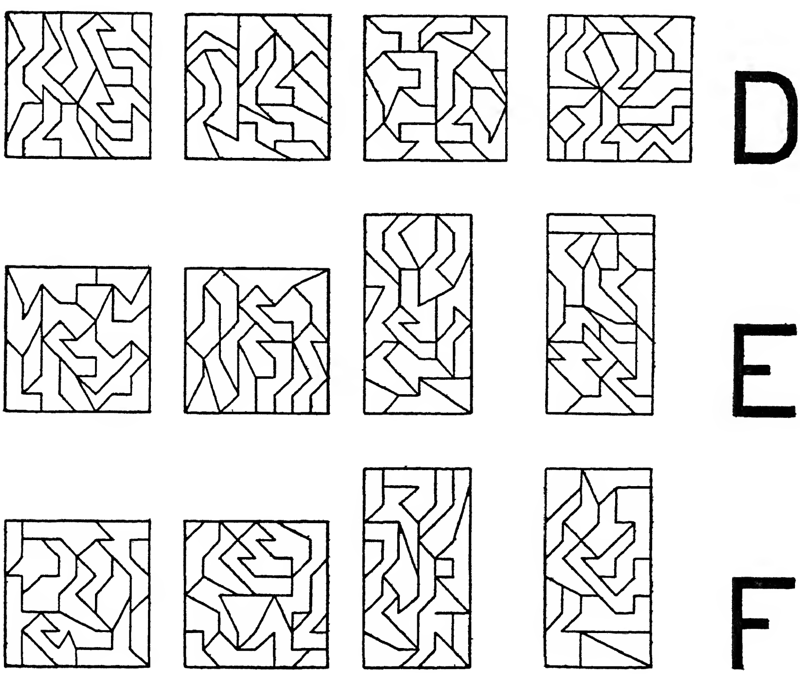


FIGURE 11.

blotter 18″ by 24″; he gave his response; the strip was removed; the experimenter announced *Right* or *Wrong*. The results for lengths 5, 5¼, 5½, 5¾ inches were as follows for the first fifteen trials:

"Number correct (out of 24) in successive trials, 1, 1, 6, 1, 2, 4, 2, 3, 7, 4, 6, 2, 3, 7, 5. In groups of three we have 8, 7, 12, 12, and 15 right out of 76.

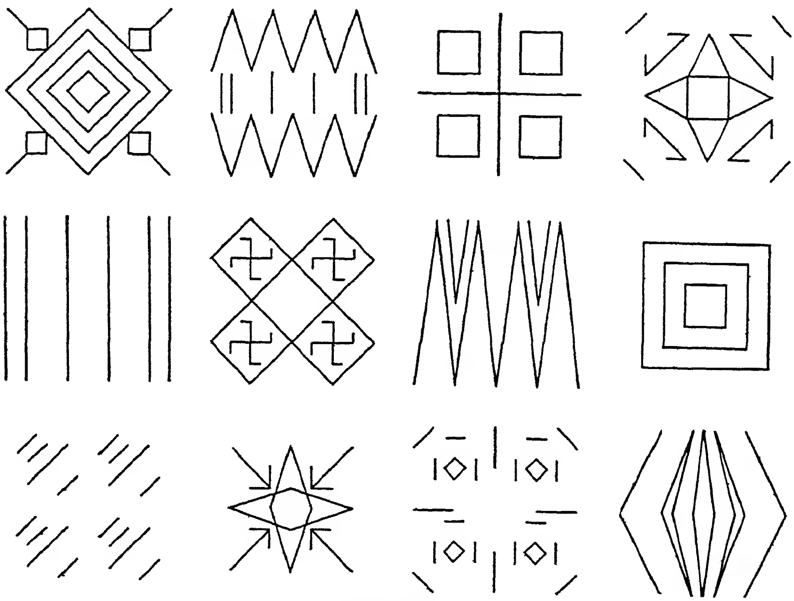


FIGURE 12.

"Consider also the learning first to connect each of the twelve shapes shown in Figure 10 with *a*, *b*, or *c*, and second to connect each of the twelve shapes shown in Figure 11 with *d*, *e*, or *f*.

"The former is easy. Very likely the reader has learned it already and can give the correct letters for the series in the changed order shown in Figure 12. The latter is hard. If you will have a dozen friends repeat the correct connections, as shown in Figure 11, ten times, and then test them with Figure 13, which gives the shapes in a changed order,

few of them will have all twelve correct. (The correct responses are *f, e, f, e, d, d, f, d, e, d, e, f*).

"The greater difficulty of the second task over the first, and of the fourth over the third, illustrates the principle which I have called the identifiability of the situation; that,

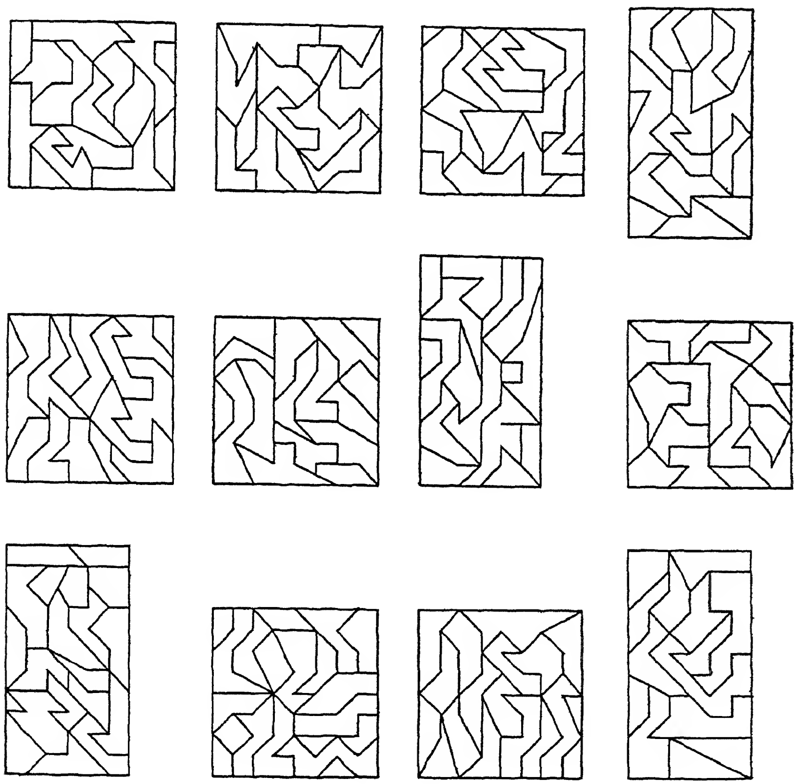


FIGURE 13.

other things being equal, connections are easy to form in proportion as the situation is identifiable, distinguishable from others, such that the neurones can grasp and hold and do something with or to it." [Thorndike, '31, pp. 82ff.; quoted with minor changes.]

The identification or placement of a situation, or part of a situation, is often a first response of the nervous system

to it, whereby it is recognized, or tagged, or pigeon-holed, or otherwise individualized and made a *terminus a quo*. Connections may then be made to one or another response. The more obvious connections of doing some overt act or having some notable thought or feeling in response to a situation are often responses to it as thus identified, distinguished, or placed, and depend on underlying or precedent connections of identification.

Much of learning consists in changes in the identifiability of situations. Their identifiability may be increased by analysis which turns them into compounds or complexes of features which are easier for the mind to grasp and retain than the original situations. We can thus easily learn differential reactions to, say, a hexagon and an octagon of equal areas, by first identifying them by counting the sides.

It may be increased by association, which connects them more or less unambiguously with something that is more easily identifiable than the situation itself. The connection is often with some symbol such as a word. Having learned to call certain things bread, butter, dogs, automobiles, red, green, a small piece of bread, a loaf of bread, a cubic inch of bread, two slices of bread with butter between, and the like, we translate situations into these easily identified verbal symbols and preserve them in mind as such. We proceed to react to them in accordance with these easily identifiable symbolic equivalents. We also label the situations with such. Every dog you see has the word dog attached to it almost as if it sounded from its head or were written on its back. A gesture, a memory of typical actions, or any other associate which can be fairly unambiguously connected with the situation and is itself easily identifiable will of course serve as the symbol. Moreover, the associated identifier may not be symbolic. Anything that is more easily identifiable than the situation itself will serve. Thus a person seeing an animal may think of it as "the one I saw before," though not in words.

A person trying to estimate lengths may connect with one

of them the idea of "smallest of the lot," though not in words. A person may identify a certain part of space as "to the right of the door a little out from the wall, at the left of the wastebasket," but not in words or gestures.

Finally, a situation may conceivably become more identifiable with repetition through sheer self-establishment in the mind or brain, without inner analysis or outer attachments. So the face of a fellow-commuter, at first subject to confusion with many others, may perhaps win distinctness, though no analytic treatment has been applied to his features, and no name or epithet or other external adjunct has been attached to him.

There are two notable special varieties of such improved identifiability by analysis and association.

First, elements of situations which are hard to identify because they are hidden qualities or features are analyzed out into relief, are made identifiable by having attention directed specially to them and by the action of varying concomitants and contrast. The results are of very great importance for learning, especially the learning of man. Times, numbers, lengths, volumes, weights, colors, mass, density, force, heat, light, molecules, atoms, nouns, verbs, and the like have to be made thus identifiable before we can profitably learn facts about them.

Second, situations which are hard to identify because they are varying amounts or degrees of some one quality like length, area, weight, brightness, temperature, health, intelligence, and the like are identified by the aid of measurement with scales, crude or refined.

§ 3. Availability

Consider now the principle of availability or get-at-ableness of the response. Other things being equal, connections are easy to form in proportion as the response is available, summonable, such that the person can have it or make it at will. Compare these two cases of learning: first, to draw with the eyes closed and with one quick shove of

the hand a line 5 inches long (i.e., between 4¾ and 5¼ inches long) in response to the situation, the sound of *C*, and similarly for 3, 4, 6, and 7 inches in response to the sounds of *A, B, D,* and *E*; second, to touch your left eye with your right hand in one quick movement in response to the situation, the sound of *F*, and similarly to touch your nose, right eye, right ear, and upper lip in response to the sounds *G, H, I,* and *J*, starting the hands always from your right knee as you sit.

The responses of moving the hand from the knee to the right ear, right eye, left eye, nose or upper lip, though much less simple than the shoves of approximately 3, 4, 5, 6, or 7 inches, are more available. Your brain knows what to do to get your hand to your nose; it can do this for you whenever you say so; you can summon the response and connect it with an identifiable situation. But your brain does not know what to do to get your hand to shove a pencil point approximately 5 inches. After it has done so and been rewarded by *Right* a score of times it is still far from secure in the performance. You can learn very quickly to give the order for 5 inches at the situation *C*, 3 inches at *A*, 4 inches at *B*, 6 inches at *D*, and 7 inches at *E*, but giving the orders does not get the movements. The difficulty is not in connecting the responses properly with *A, B, C, D,* and *E*, but in getting them at all so that you can connect them with anything. They are not readily summonable or get-at-able.

Experiment 44 in drawing 3-inch, 4-inch, 5-inch, and 6-inch lines at command with eyes closed is a good illustration of the slowness of learning due to the unavailability of the responses required. In the case of our twenty-four subjects trained with announcements of *Right* and *Wrong*, the percent of responses with ⅛ inch in the case of the 3-inch lines, or ¼ inch in the case of the others, rose from an average of 13 percent right to an average of 25 percent right as a result of 4200 trials. Two subjects who continued the training so as to have 21,000 trials in all increased their

percentages of rights to around 90. If the learning had been to put the hand on the right eye, nose, upper lip, and forehead, respectively, at the signals 3, 4, 5, or 6, these same subjects would have increased their percentages correct from 0 to 100 in less than one thousandth of this number of trials.

Much of learning consists in making certain responses more available, more easily summonable. In infancy and childhood we acquire a repertory of responses such as sitting down, putting on our shoes and saying words, in the form of unitary end terms which we can evoke in suitable circumstances more or less at will. To these we add variously all sorts of special skilled acts, as in billiards, tennis, handwriting, typewriting, or singing, in similar accessible form.

Unavailability may be of different kinds and degrees. One may be unable to make the response at all, as with moving the ears in the case of most of us or blowing the nose in the case of little children. Or one may be able to make it satisfactorily, even perfectly, but not at will, as in the case of sneezing or accelerating the pulse. Or one may be able to make it with a rough approximation but not within the limits of error required, as in the case of our line drawing at the start, or in the case of a child printing an *h* that is distinguishable from a *b, l, k,* or *t*. Or one may have some or all of the components of the response available, but not be able to make them together at all, or at will, or in proper form or order.

Consequently the attainment of greater availability may consist in exciting the response, in analyzing it out from a response containing it, in connecting it with some status or cue which is available, in reducing its errors, or in constructing it out of available elements.

If a situation is identifiable and a response is available, the task of strengthening the connection from the former to the latter is easy for the time being. We have simply to arrange matters so that the response is attached to the

situation and reward the connection. The difficulty will be to prevent its loss by disuse or the confusion of some other response with it. There is, of course, also often the practical difficulty that the connections in question lack intrinsic interest so that repetitions of them have relatively little influence.

The principles of identifiability of situation and availability of response have extensive applications and are helpful in the understanding of many facts. Consider, for

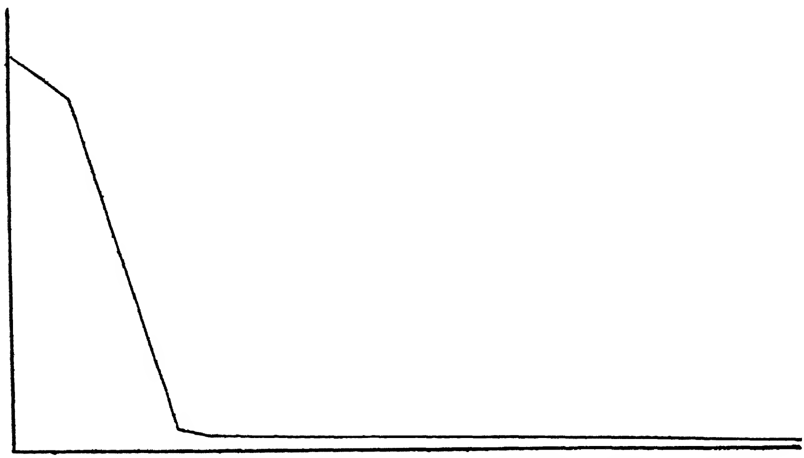


FIGURE 14a. Learning curve illustrative of sudden improvement.

example, these questions: (1) Why do cats, dogs, rats, and monkeys learn rather easily to respond after a "delay," or period of absence of the situation, to the place where they have seen food put and with much more difficulty to the shape or color or size of the container in which it was put? (2) Why does the curve of learning for some tasks with some animals drop rather suddenly as in Figure 14a, and for other tasks or other animals drop gradually as in Figure 14b? (3) What essential differences are there between so-called "conscious control" or "conscious learning" and so-called "unconscious learning"? (4) Between learning by the selection of an impulse and act and their association

with a situation, and learning by ideas? (5) Why are such skills as typewriting, swimming, or tennis slow in being learned but long remembered and quickly relearned?

The answer to the first question seems to be that the locations are facts relatively more, and the form, color, size are facts relatively less, identifiable by these animals than by us. In general, such differences in identifiability explain much in the learning or lack of learning displayed by animals. Thus, associations leading from numerical facts,

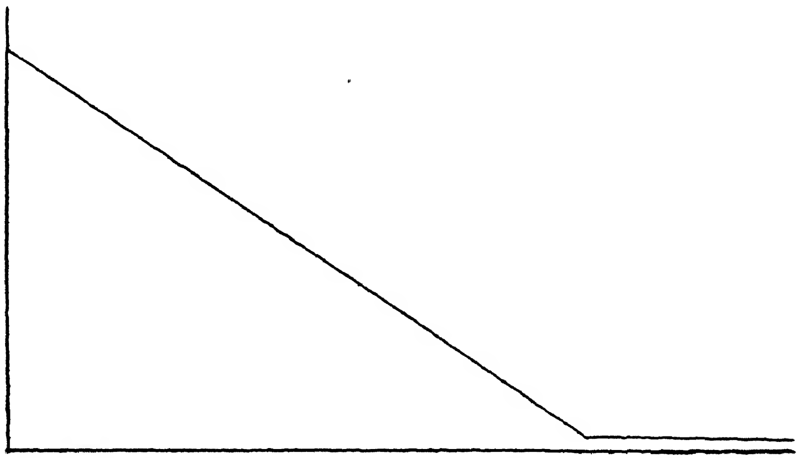


FIGURE 14b. Learning curve illustrative of gradual improvement.

which are very, very easy for us to form, may baffle them entirely.*

A complete answer to the second question would, of course, involve many facts, but identifiability and availability go a long way in cases where the curve tells the story of repeated experiences with one same situation, as when a cat is confined time after time in the same puzzle-box, or a monkey is repeatedly confronted with a certain signal. In such cases, if the learning is purely associative, that is,

* On the difficulty of numerical features see Carr '17, Hunter '18, '20, and '28, Woodrow '29, and the results obtained with such arrangements of the Yerkes multiple-choice apparatus as "Third door from the left" or "Third door from the right."

if the essential feature of the situation is identified and the response is available, so that all that has to be learned is that the latter goes with the former, the drop will usually be sudden. If the drop is gradual, it is evidence that the learning involves increased identifiability of the situation or availability of the response. A gradual drop in the curve for time or errors or some composite of them need not mean that the connection *per se* is slow in forming, but that one of the things to be connected is slow in emerging into a condition of facile control.

If, for example, the task is to open a door by depressing an ordinary thumb-latch and at the same time pushing against a door, the slow drop may be due partly to the extrication of the thumb-piece and door from the gross total situation and the establishment of individualized perceptions of them as first responses. It may be partly due to development of the responses of "pushing down on that thing" and "pushing out on that other thing" as available acts.

As regards the third and fourth of our questions, it appears likely that the presence of consciousness of what we are learning, or of ideas of the situation or the response, is rather a sign of a high degree of identifiability or availability than a force in itself. I suspect that if the adaptive or right response is available and is made to a situation which is identifiable, learning will be rapid, whether or not the individual has any ideas of the situation or the response, and regardless of any consciousness that he may have beyond what is a consequence of the identifiability and availability in the case.

So kittens will quickly learn to pull down a string hung across a certain part of the top of a box, though there is no good evidence that they have ideas of the string or of pulling it down. So rats, after exploration of a maze or room which identifies its main features and makes available the acts of getting from one to another spot in it, may very quickly learn to go from one spot to the food box, though

without demonstrable inner representations of its topography. So, in my opinion, may we.

The answer to the fifth question seems to be that the responses require much practice to reach the status of easy availability required to secure much improvement in score and that consequently their connections with appropriate situations are by then very, very firmly fixed, "overlearned" as the psychologist says. For example, by the time a person has the series of responses of typewriting *t, h,* and *e* in that order as an available unit, he has it very firmly bound to the sight or thought of the word *the*. This leaves us with the problem of why the increased availability of the responses in skilled acts is itself so little weakened by disuse. We can make one step toward the answer by noting that increased availability seems in all cases to be specially durable. Various explanations may be offered for this.

The principles of identifiability and availability are of great importance in education, mental hygiene, and all forms of human engineering. Consider, for example, how much of the learning of the sciences consists in making identifiable the facts and ideas corresponding to 3, 4, 5, ratio, power, root, integral, parabola, atom, electron, potential, oxygen, hydrogen, cell, chromosome, gene, wealth, price, value, enzyme, antibody, situation, response, connection, inhibition, I. Q., delayed reaction, negative adaptation, apraxia, conditioned reflex, and similar words. Consider what the practical consequences would be of making the sense of well-being, cheerfulness, self-respect, courage in the face of physical danger, and other such inner attitudes and emotions as available as now are the responses of combing one's hair, brushing one's teeth, or saying "Yes."

Much of common knowledge and of science consists in making elements, features, and aspects of some thing or animal identifiable so that we may easily recognize them, form habits of dealing with them, and prophesy their behavior. Much of work, play, technology, art, and morals

consists in making certain movements, attitudes, desires, and tendencies available in certain situations where they are needed, so that, for example, we can sing a note exactly, or shoot straight, or keep a stout heart and steady pulse against a foe. Especially important are those cases where the act or state is made so available that the person can do it or be it almost or quite at will.

Instructive experiments, requiring a volume like this to report them, might be made on ingenious procedures to identify various important elements or qualities. The general principles in such analytic activities I have described elsewhere.* In one sense details about them would be appropriate in this volume on the fundamentals of learning. For they operate early in infancy and much of our later connecting is done with parts or qualities of situations which have been previously made identifiable.

Still another volume might report instructive experiments on ways and means to make responses of muscles, of glands, and of the neurones themselves more available. The modern teaching of phonetics and of swimming, for example, offers excellent illustrations of the arrangements of ingenious situations which stimulate certain responses and start them on the way toward availability.

Any feature of a situation which the mind can grasp and segregate can, by repetition and reward, be connected as strongly as we wish with any response which the mind can summon. The scientific control of connection-forming with an identifiable situation and an available response involves only the straightforward application of the laws of belonging and effect. The procedures by which undifferentiated, confused, and elusive facts can be made stable and fit for the mind's use and by which greater availability can be attained in the case of movement, attitudes, and feelings, have been indicated, but they need and deserve much experimental study.

* *Educational Psychology,* Vol. II, "The Psychology of Learning," '14, pp. 32-46.

CHAPTER XIV

The Influence of Mental Systems

§ 1. The complexity of mental connections

The connections which we have investigated so far have been simple links between an external situation and an overt response or, less often, between the first and second terms of a simple pair, such as a word heard and a number heard or thought of. Each has also been, as a rule, a rather independent unit by itself easily isolated from the rest of the person's behavior and learning.

Such uniformity, simplicity, and independence are desirable in experiments on the fundamental questions with which we have been concerned, but it would be unfortunate if either we or our readers got the impression that they are characteristic of the actual connections which are formed in the world's learning. On the contrary these are usually varied, complicated, and influenced by their contexts.

Connections lead from states of affairs within the brain as well as from external situations. They often occur in long series wherein the response to one situation becomes the situation producing the next response and so on. They may be from parts or elements or features of a situation as well as from the situation as a whole. They may be largely determined by events preceding their immediate stimuli or by more or less of the accompanying attitude or set of the person, even conceivably by his entire make-up and equipment. They lead to responses of readiness and unreadiness, awareness, attention, interest, welcoming and rejecting, emphasizing and restraining, differentiating and relating, directing and coördinating. The things connected may be subtle relations or elusive attitudes and intentions.*

* Each sentence in this paragraph could well be made the subject of a

In some cases the part or aspect is much more important than the gross total. This is rather the rule with seen words, for example, in which the pattern is the essential. Whether the word is black or blue or red or gray, whether the print is large or small, whether it is sensed by cones in the right or the left side of the fovea, does not matter. In hundreds of varying gross total sense impressions the same pattern is used to connect with the main response. The color of the word or its size or its position in the line is responded to as an accessory of the pattern. Something of the same sort is true of heard words, musical phrases, geometrical forms, and common objects in which a pattern dominates.

Connection and selection coöperate in intimate ways. A very common type of connection is one in which the situation evokes as its response whatever acts attain a certain result. The situation being, for example, the sight of a letter to be signed, the response is to do whatever particular movements get it signed. The particular movements may vary according to whether pen or pencil is at hand, and where the letter lies. The connection is in the nature of an order to do what seems suitable until the goal of getting said letter signed is attained. Such *order*$\longrightarrow$*fill it* connections may lead to much selection of ways and means. If the selection is important and obvious, we call them problems and solutions rather than situations and responses. But there is no fundamental distinction between *Letter to be signed*$\longrightarrow$*signing it* and *Square root of 729638 to be computed*$\longrightarrow$*computing it.*

As a result of the variety of responses, piecemeal activity (that is, connections from and to elements or aspects), differential potency, coöperative action, the mixture of selective procedures with associative, and the determination of

chapter if this volume were a general account of mental connections. But as it is a report of new facts, and we have made few or no experiments which bear specifically upon these topics, we pass all of them by except two. Readiness has been discussed in Chapter XIII and Mental Set will be discussed in Chapter XV.

connections by mental trends and sets, the connections of a human mind are complicated almost beyond description. Almost every prophecy which we make about a man's behavior has to be prefaced by "other things being equal." The thinking and learning of a single ten-year-old for a single day would present a picture hardly recognizable as a collection or system of S⟶R connections of the simple type studied here. Many psychologists would indeed deny that any system of connections was adequate to explain his behavior, and would invoke powers of analysis, insight, purpose, and the like to supplement or replace the simple process of connection-forming by repetition and reward.

In this chapter we shall deal particularly with the frequent and important action of certain mental systems which seem, at least on the surface, to compete with the laws of habits and be inexplicable by them.

§ 2. Mental systems apparently unexplained by ordinary connections

Experiment 86

Consider the following experiment: The subject is given a sheet like that reproduced (with dimensions altered somewhat) on the following pages. The sheet is laid before him bottom side up and he is asked to turn it over, read the directions, and follow them.

The responses will vary from such as are easily explainable by frequency and fitness such as *ba, fi, jo, afraid of, bread and, cold day, dear sir, inside, long time,* and *yours truly* to responses which have had a relative frequency in his past writing of less than 1 in 100, such as *bc, fg, qr, afraid fear, cold warm, dear fear, in out, long short, no yes,* and *yours mine.*

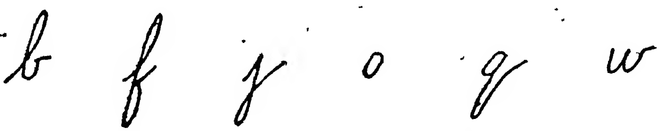
The records from a hundred or so educated adults will vary from ones like H and H1, shown below, to ones like S and S1. Most of them, however, will display both kinds of tendencies. For the average educated adult the obviously habitual responses to the sixteen words will number

Experiment 86

Copy Line I three times. Then write it, adding one or two strokes to each of the five things. Do not think about what strokes you are to add, but just continue with any movement that you feel like making in each case.

I. 

Write the letters of Line II, adding one letter to each of these letters. Do not think about what letter you will add, but just add any letter that you feel like writing.

II. 

Write the words of Columns III and IV, adding one word to each of them. Do not think about what word you are going to add, but just add in each case the first word that comes into your head.

III	IV
afraid	on
bread	result
cold	slow
dear	sour
in	tenth
long	wish
needle	working
no	yours

Records from two individuals, consisting mainly of habitual sequences

III	H	H1	IV	H	H1
afraid	go	of	on	time	to
bread	eat	and	result	will	of
cold	water	hot	slow	time	fast
dear	old	me	sour	grapes	sweet
in	house	to	tenth	time	part
long	time	ago	wish	could	I
needle	point	and	working	time	hard
no	need	yes	yours	truly	truly

Records consisting chiefly of responses not attributable to habitual sequences

	III S	III S1
afraid	man	fear
bread	butter	eat
cold	hot	warm
dear	beloved	mother
in	out	out
long	short	short
needle	pin	thread
no	yes	yes

	IV S	IV S1
on	off	table
result	answer	good
slow	fast	fast
sour	sweet	sweet
tenth	fifth	eleventh
wish	like	to
working	resting	hard
yours	mine	mine

Average records from educated adults

	III Av.	III Av.1
afraid	fear	to
bread	butter	butter
cold	hot	hot
dear	one	child
in	side	out
long	sought	short
needle	thread	thread
no	yes	yes

	IV Av.	IV Av.1
on	up	top
result	answer	problem
slow	swift	sure
sour	milk	sweet
tenth	eleventh	time
wish	fairy	that
working	man	hard
yours	truly	truly

about 9, and the other responses about 7. The records Av. and Av.1 are samples.

We present a distribution table for a group of 110 adults (Table 125). In this experiment the subjects are, so to speak, tempted to follow the beaten tracks of habit by being required to write the word and then the word that comes to the mind or fingers. If the task is simply to look at or hear the stimulus word and write or say the first word that comes to mind, connections like *Yes*→*sir*, *Yours*→*truly*, *afraid*→*of*, and *sour*→*grapes* operate less often and tendencies to think of opposites, synonyms, members of the same class of facts, and the like operate oftener. For example, 109 educated adults performed the experiment described on page 355 and a day later took the Kent-Rosanoff test (given as a group test, with the stimulus words pre-

Table 125

Distribution of the strength of the tendency to respond to certain words by obviously habitual verbal sequents

Number (out of 16) of Responses like (afraid) of, (bread) and, (cold) day	Frequency of Occurrence in 110 Educated Adults: in Percents
16	11
15	3
14	7
13	7
12	2
11	10
10	9
9	8
8	5
7	6
6	5
5	4
4	7
3	5
2	9
1	2
0	0

sented orally and an allowance of five seconds for writing the responses). In the latter, 71% of them wrote *hot* after *cold* and none wrote *as*. 77% of them wrote *fast* after *slow* and none wrote *as* or *down*. *Sour* was followed by *sweet* in 63% of the cases and by *as, milk,* and *grapes* in 0, 0, and 5%, respectively. *Afraid*$\longrightarrow$*of, wish*$\longrightarrow$*to, wish*$\longrightarrow$*that,* and *long*$\longrightarrow$*as* appeared 0, 0, 1, and 0 times. If the individuals had not first taken the earlier experiment, the 71, 77, and 63 would perhaps have been even larger.

It is obvious from these samples, or from the results of any free-association test like the Kent-Rosanoff, that a word does not always, or even very often, evoke the word which has followed it oftenest and with most satisfying consequences in speaking and writing. More often it evokes a word which is a synonym, or an opposite, or completes suitably the sentence *S* (*the Stimulus Word*) *is a* . . . , or *S is a case of* . . . , or *S is illustrated by* . . . , or otherwise fits in some mental system with S.

Such mental systems might be of four (and perhaps more) sorts. First, there might be sensory systems whereby a stimulus which belonged in one sense-field, say hearing, would tend to evoke responses in sense-field, beyond what repetition and reward could account for. Second, there might be instinct-systems whereby a stimulus which had a place in some original or early established tendency, such as *being thwarted in movement*⟶*struggle, weariness*⟶*states of rest, anger*⟶*blows*, or *courtship* ⟶*mating* behavior, to evoke responses constituting that original tendency beyond what repetition and reward could account for. Third, there might be (and surely are) customary systems like the alphabet, the number series, the family or the schoolroom, whereby stimuli which were parts of these systems would evoke other parts thereof. Such customary systems would themselves have been built up by the ordinary action of repetition and reward, but once established might exercise a dominion of their own. Finally, there might be what I shall call transcendent systems, not referable to any organization of the brain to fit either its systems of receptors, or its systems of connections subserving eating, defense, sex behavior, or the like, and certainly not created by experience, exercise, and effect. There might conceivably be, for example a tendency inherent in mind for the thought of any quality to arouse the thought of the opposite of that quality, or a tendency for the thought of any whole to arouse thoughts of its parts, regardless of what particular connections had been formed in the mind in question.

Experiment 87

Experiment 87 was planned to secure facts about the influence of systems in directing the course of thought and, in particular, to ascertain the probability that the original organization of the brain or mind directs thought otherwise than by the formation of connections by exercise and effect, that is, by repetition, reward, and punishment.

This form of the experiment was the well-known free-association test, used by Kent and Rosanoff, the stimulus words being chosen to give opportunity for sense-fields, instinct systems, customary systems, and what we have labelled transcendental systems to operate.*

Among the stimulus words are:

(1) *loud, music, patter, rumble,* and *thunder*;
(2) *hard, rough, soft,* and *smooth*;
(3) *bitter, bread, butter, cake, cheese, cabbage, eating, fruit, gravy, mutton, pie, salt, soup, sour, sweet, tobacco,* and *whiskey*; and
(4) *black, blue, dark, green, moon, red, white,* and *yellow.*

Do the responses to these show any evidence of greater frequency of response within the sense-field of the stimulus than can be accounted for by the laws of exercise and effect?

Among the stimulus words are *hungry, thirsty, afraid, anger, joy, man, woman, boy,* and *girl.* Do the responses to them show evidence of the direction of response by organization around certain fields or strands of original interests and aversions?

The influence of certain customary systems, due to circumstances and habit, will be studied in the responses to such groups of stimulus words as *add, decimal, multiply, fraction, 4, 6, 7,* and *8*; *oui, merci, garçon,* and *maison*; *t, b,* and *u*; *doctor, health,* and *sickness*; *coat, collar, hat,* and *shoe.*

The influence of what we have termed transcendental systems may be studied in the responses to *ball, cone, crooked,*

* Various objections can be made to the assumption that we obtain the mind's usual responses to a word when we ask a subject to write the first word that comes to his mind upon hearing or seeing it. We do not here make that assumption or any other save that the persons concerned coöperated willingly, understood the instructions, and wrote or said the first word that they thought of unless it was such as they were ashamed to write. Instances of such discreditable thoughts were probably extremely rare in our group, well under one-tenth of one percent. The use of the free-association technique in general is an important topic, and we have studied certain aspects of it in detail. The facts are reported in Appendix IX.

square, and *triangle*; *always, future, later,* and *now*; *Boston, Chicago, Italy,* and *Paris.* If the brain of man is so organized as to have its actions directed by shape, time or locality as abstract forms of thought imposed upon the organization due to ordinary instincts and habits, the fact may be revealed by the responses to these stimuli. Also evidence of a subtler character may be sought in ways to be described later.

§ 3. Sensory systems

The number of responses to *loud, music,* etc., *hard, rough,* etc., *bitter, bread,* etc., *blue, green,* etc., which are suggestive of hearing, touch, taste, and color vision, respectively, is very large. Whether there are more than would be expected by frequency and fitness is, however, very doubtful. The lists in summary form are given below. There are a few responses, the appearance of which is easy to explain by attraction toward one sense-field, and hard to explain by frequency and fitness. These are as follows: loud ear, 1; patter thump, 1; soft sand, 1; smooth touch, 1; smooth soft, 16; smooth brittle, 1; smooth hard, 5; cheese lemon, 1; cheese sour, 1; cheese vinegar, 1; salt soda, 1; cabbage syrup, 1; soup syrup, 1; blue orange, 2; blue pink, 4; green pink, 1; red indigo, 1; red pink, 6; red tan, 1; yellow gray, 1.

Summary Lists

Hearing

(162) *loud:* soft, 39, noise, 56; noisy, 6; bang, clap, cornet, crash, drum, ear, quiet, radio, sound, still, talk, voice, yell, 27.

(162) *music:* piano, 12; song, 19; band, concert, drum, fiddle, melody, noise, opera, orchestra, organ, saxophone, sound, tone, trombone, violin, 37.

(192) *patter:* chatter, clatter, noise, sound, talk, thump, 19.

(192) *rumble:* noise, 35; hear, mumble, patter, rattle, roar, sound, still, talk, thunder, 31.

(162) *thunder:* crash, loud, noise, roll, 16.

Touch

(192) *hard:* soft, 95; glass, iron, nail, rock, stone, 26.

(162) *soft:* hard, 62; bed, candy, chair, collar, cushion, down,

feathers, etc., making a long list of things which feel soft, summing to 48; also feel and felt, 3; mushy, 2; pressure, 1.

(162) *smooth:* rough, 55; soft, 16; brittle, cloth, even, floor, hard, lead, satin, sheet, silk, skin, velvet, 28.

(162) *rough:* smooth, 49; board, cloth, hard, material, paper, sandpaper, touch, 9.

Taste

From the many words in our lists, I select *cheese, eating, salt,* and *bitter* for summary.*

(192) *cheese:* bread, butter, cake, crackers, eat, lemon, milk, pie, salad, sandwich, sour, vinegar, 61; cream, Roquefort and other names of varieties of cheese, 35.

(162) *eating:* food, 30; dinner, lunch, supper, 8; bread, cake, candy, chicken, corn, dumplings, eggs, fish, meat, pie, steak, 22; bitter, salt, sour, and sweet never appear.

(192) *salt:* pepper, 20; sugar, 22; almonds, bread, food, meat, savor, soda, soup, taste, tasty, 28; bitter, 8; sour, 8; sweet, 6.

(162) *bitter:* sweet, 99; salt, 6; sour, 6; taste, 6; acid, almond, aloes, chocolate, drink, fruit, lemon, lemonade, medicine, persimmon, quinine, sweets, tang, 27.

Color

(192) *blue:* all but 11 are of visual objects or qualities, including black, 10; gray, 3; green, 6; orange, 2; pink, 4; red, 19; white, 6; yellow, 6.

(162) *green:* all but 8 are visual, including black, 2; blue, 16; gold, 1; pink, 1; red, 22; white, 3; yellow, 11.

(162) *red:* all but 6 are visual, including black, 5; blue, 32; carmine, 1; crimson, 1; green, 19; indigo, 1; orange, 2; pink, 6; scarlet, 1; tan, 1; white, 9; yellow, 5.

(192) *yellow:* all but 8 are visual, including black, 3; blue, 9; gold, 2; gray, 1; green, 15; orange, 7; pink, 5; red, 9; white, 7.

On the whole, there is some, but far from conclusive, evidence that the impressions received from any one system of receptors are somewhat affiliated and that their affiliations produce affiliations between the ideas which develop from these impressions, with the result that an idea which has been equally often and profitably connected with two ideas,

* The entire list has been searched for responses hard to explain by frequency and fitness, and these are typical of all that were found.

one inside that sensory field and one outside it, will have a somewhat stronger tendency to evoke the former. Further experiments, and experiments of a more crucial character are necessary to settle the question. One thing is sure from even our rough survey. The power of attraction within a sensory field, if it exists, is not great. If it were, we should find words like *shrill, squeaky, cry, laugh,* and *sing* occurring oftener as irrelevant (except as being sound words) responses to *loud, music, patter, rumble,* and *thunder.* Similarly, *tickle, scratchy, wet, slimy,* and *itch* should occur oftener as responses to *hard, soft, smooth,* and *rough. Sweet, sour, salt, bitter, fruity,* and *oily* should occur oftener as responses to *cheese, eating,* and the like. They are very rare as responses to *bread, fruit, gravy, mutton, pie, soup, tobacco,* and *whiskey,* the total for *sweet, sour, salt,* and *bitter* being 7, or about one response out of two hundred.

§ 4. Instinct systems

I have inspected the responses to *hungry, thirsty, afraid, anger, joy, man, woman, boy,* and *girl* for any indications of tendencies for thought to be organized by the instinctive activities of food-getting, fear, anger, sex, and family life. There are very few such, but this may well be because these words are not very well adapted to elicit them, and because some of them may have been repressed. I will present the details in the case of *anger* which is typical.

The commonest original provocatives of anger are thwarted impulses or expectations and pain. Among its common original expressions are a hot feeling, struggling, yelling, and blows. Among 124 responses to *anger,* the only ones suggesting any of these original provocatives and expressions are fight, 1; heat, 1; hot, 2.

§ 5. Customary systems

Of the existence and potency of these there is no doubt. *4, 6, 7,* or *8* evokes some other number in about 40% of the

cases, and the word *number* in about 15%. *Add, decimal, multiply,* and *fractions* evoke *arithmetic, number,* or *figure* in about 35% of the cases and the name of some other arithmetical operation in about 25%. *Oui, merci, garçon,* and *maison* evoke their English meanings in about half the cases. The letters *t, b,* and *u* evoke the word *letter* in about a fifth of the cases and some individual letter in about a third of them. *Coat, collar, hat,* and *shoe* have frequent sartorial sequents due to the systems built up when we dress ourselves, buy our clothes, and the like. They have other local sequents due to the systems built up as we dress ourselves or look at other persons. So out of 192 responses to *hat* we find *cane, cap, chapeau, cloak, clothes, clothing, coat, dress, hook, rack, sleeve, scarf, shoe* occurring 81 times, and *head* occurring 32 times.

These systems are created by the laws of exercise and effect, things being kept together in the mind which have gone together often and with resulting satisfaction. They are not different in their fundamental causation from the tendencies which make us respond to *2 × 7 = ?* by *14* or to *Say the alphabet* by *a, b, c, d,* etc., or to *Columbus discovered* by *America.* They are elaborate groups of connections and interconnections just like the simple pairs which we have experimented with.

Before attacking the problem of transcendent systems, we may well consider certain significant features of the responses taken as a whole. A striking difference between the connections revealed by these experiments and the illustrations of trains of thought given in psychology books is the greater utility and reasonableness of those shown by the experiments. Almost all of them are appropriate, the connections of the words matching the connections of reality to a notable extent.

This may be occasionally due to a deliberate rejection of words which came to mind but seemed to the individual to be silly or unworthy of him. But unsigned replies to the question "How many times did you not write down the first

word that came to mind, but wait for a second more suitable one?" show that this is relatively unimportant.

The fact is that in educated adults, when a word is to be thought of at the sight of a word, the mind quite automatically thinks of a word that belongs with or is appropriate to the stimulus word.

This appropriateness or relevancy often takes one of the following forms:

The response is a synonym of the stimulus word
" " is an opposite
" " completes the sentence *S is* . . . or *S is a* . . .
" " " " " *is a part of* . . .
" " " " " *has* . . . *as one of its parts*
" " " " " *is a case of* . . .
" " " " " *is illustrated by* . . .
" " " " " *belongs in* . . .
" " " " " *makes* . . .
" " " " " *is made by* . . .

and so on with other forms of relevancy to the indefinite *S has to do with* . . . , or *With S* . . . *has to do.*

If scholastic philosophers had made word-association experiments they would probably have stated laws of association by similar meaning, by contrariety, by relation to whole, by relation of genus to species, by relation of species to genus, and so on, ending, perhaps, by relations miscellaneous.

Present believers in forms of organization which transcend instinct, habit and sensory affinities would not presumably go as far as this (though it would be hard for them to decide just where to stop). Since we are engaged, not in a debate, but in a search for the truth, we shall not impute any decision to them, but shall simply examine the facts to learn whether organization by systems due to habit is adequate or inadequate.

§ 6. Transcendent systems

We shall take first the form of relation which makes the strongest case for the transcendent systems, namely, opposition or contrariety. If the tendency of ideas and words to evoke their opposites can be explained as a consequence of repetition and reward, we need not go further. If it seems to transcend these simple facts, we can proceed to examine the weaker cases in turn.

*Responses by Opposites**

The tendency to respond to certain words by their opposites is, especially in intellectual adults, very strong. We find the following percentages: *Add*⟶*subtract, 33; multiply*⟶*divide, 30; crooked*⟶*straight, 36; square*⟶*round, 19; pro*⟶*con, 43; hot*⟶*cold, 43; future*⟶*past, 19; now*⟶*then, 27; sour*⟶*sweet, 32; sweet*⟶*sour, 28.* These percentages average 32½.

But these facts are not evidence that oppositeness in and of itself has a general potency. That is disproved by the following facts. First, the words which often evoke their opposites also, though less often, evoke their synonyms. We have, for example, percentages as follows: *hot*⟶*warm*, 3; *now*⟶*present*, 11; *always*⟶*never*, 28, and *always*⟶*ever* (or *forever*), 27; *beautiful*⟶*ugly*, 12, and *beautiful*⟶*fine* (or *pretty* or *lovely*), 9; *late*⟶*early*, 38, *late*⟶*tardy*, 9.

Second, the foreign words almost never evoke their opposites. *Oui*⟶*non* (or *no*); *garçon*⟶*fille* (or *mademoiselle* or *girl*), and *nein*⟶*ja* (or *yes*) occur in only 5 percent of the cases, though *yes*⟶*no*, *boy*⟶*girl*, and *no*⟶*yes* would appear in about 60 percent.

* We report as Table 128 at the end of this chapter certain facts about the responses to the words used in Experiment 87, including the frequency of the opposite oftenest given. Table 128 is the source of many of the facts which will be used in the argument. A reading of this table will also be useful to give a general sense of the connections which are commonly aroused by words in the free-association procedure.

Third, *4, 6, 7,* and *8* never evoke *—4, —6, —7, —8, 1/4, 1/6, 1/7,* or *1/8*; though the opposite is especially definite and complete in these cases. The percents are 0, 0, 0, and 0.*

Fourth, the forms with *dis, in,* and *un* as prefixes, or phrases with *not* are evoked very rarely. If the factor at work was oppositeness in and of itself, it should, one would suppose, express itself rather often by these clear and easily available signs. *Comfort*⟶*discomfort, justice*⟶*injustice, religion*⟶*irreligion,* and *afraid*⟶*unafraid,* comprise less than 1 percent of the responses to these four words. Of the *not-x* phrases given as responses to 60 words taken at random from our list, not one was given as a negative of the stimulus word.

Fifth, the cases of pseudo-opposites (like *man*⟶*woman, boy*⟶*girl,* and *hand*⟶*foot*) where there is no real contrariety, but rather a great resemblance with a contrast in one or more particulars, show percentages comparable to the cases where the two words represent different directions from a zero point or opposite extremes of a scale of amount of something, or acts each of which undoes the result of the other. The percentages for *man*⟶*woman, woman*⟶*man, boy*⟶*girl, girl*⟶*boy, hand*⟶*foot, foot*⟶*hand, command*⟶*obey,* and *king*⟶*queen* are 50, 52, 62, 54, 18, 14, 15, and 36, averaging 37.

Sixth, if we present the stimulus word, not in isolation but after some rather colorless word like *the* or *his* or *with,* the number of responses by opposites is lessened decidedly. If we present it in phrases or sentences like *in the sweet, and very cold, he is slow, how beautiful* or *in that rough,* and require that the first two words which come to mind be written, the number of responses by opposites is reduced almost to zero.† Table 126 shows the percentage for the

* This third line of evidence is perhaps not important since the potency might be present, being swamped by the potency of the habit system of thinking of some other number in the positive integer series.

† The requirement that two words be written does not have much effect. This is shown by facts reported in Appendix II.

TABLE 126

PERCENTAGES OF RESPONSES BY OPPOSITES

Stimulus	Percentage of Opposites	Stimulus	Percentage of Opposites	Stimulus	Percentage of Opposites
sweet	28	the sweet	10	in the sweet	2[1]
woman	52	a woman	23	for a woman	7[2]
cold	33	very cold	20	and very cold	3[3]
slow	49	is slow	13	he is slow	5[4]
beautiful	12	how beautiful	3	how beautiful	0
rough	30	that rough	8	in that rough	0
foot	14	his foot	3	did his foot	0
girl	54			nice girl	18[5]
long	52			for long	29[6]

[1] 1 in 60, *sour out*
[2] 4 in 60, *and man* (2), *for a man, my man*
[3] 2 in 60, *and hot, fire hot*
[4] 3 in 60, *and fast, not fast, she is fast*
[5] 12 in 60, *and boy* (11), *nice boy*
[6] 16 in 55, *for short* (3), *or short* (3), *too short* (3), *and short* (3), *is short, than short, short trip, short adieu*

three types of presentation for comparable groups of adult students.

A general potency of contrariety being thus highly improbable, we may ask whether one or more special sorts of it have power beyond what they could have acquired by exercise and effect. Take first the case of opposite directions from a zero or indifferent status, or from an average or ordinary status. Do cases like *warm*$\longrightarrow$*cool, deep*$\longrightarrow$*shallow, high*$\longrightarrow$*low, short*$\longrightarrow$*long, beautiful*$\longrightarrow$*ugly, future*$\longrightarrow$*past,* owe their frequency to the circumstances of experience and the laws of connection-forming, or does the thought of one direction of the scale have a peculiar power to arouse the thought of the other? The former seems more probable for the following reasons:

First, the percents vary very widely: *black*$\longrightarrow$*white, dark*$\longrightarrow$*light, hard*$\longrightarrow$*soft,* and *long*$\longrightarrow$*short* approach 50. *Always*$\longrightarrow$*never, future*$\longrightarrow$*past, swift*$\longrightarrow$*slow* and *loud* $\longrightarrow$*soft* (or *low*) are near 25. *Cool*$\longrightarrow$*warm, beautiful*$\longrightarrow$*ugly, deep*$\longrightarrow$*shallow, joy*$\longrightarrow$*sorrow, mountain*$\longrightarrow$*valley,* and *sickness*$\longrightarrow$*health* are near 10. *Afraid*$\longrightarrow$*brave, com-*

fort⟶*discomfort,* and *trouble*⟶*ease* are very, very low; and *7* to *—7* (or to *1/7*), *4* to *—4* (or to *1/4*), and the like are at or near zero. If the oppositeness were the cause of the connections, such a range could hardly occur in educated adults all of whom were well aware of the oppositeness of the two members in every case (except perhaps a very few who may not have known the meanings of *ganz* and *sehr*).

Second, the magnitude of the percent shows little or no correspondence to the perfection of the oppositeness. The negative numbers which are precisely equal and opposite divergences from a perfectly defined and known zero-condition show no effect. Long and short, which are merely designations that one dimension varies toward more or less from a mediocre condition, or from a usual or an expected condition, show a very large percentage of responses.

If we inspect the cases where the opposites are two acts or facts or relations one of which thwarts or nullifies the other, we find similar evidence against the potency of the oppositeness in and of itself. *Multiply*⟶*divide, sour*⟶*sweet,* and *pro*⟶*con* show percentages from 20 to 40, whereas *eating*⟶*vomiting, sleep*⟶*wake, memory*⟶*forgetfulness,* and *ad*⟶*from* (or *away*) approach zero. *Sour*⟶*sweet* and *pro*⟶*con* are the highest of all; *eating*⟶*vomiting* and *ad*⟶*from* score zero. Yet the latter represent just as clear and emphatic nullification.

Any potency of contrariety *per se* is thus improbable and we seem compelled to believe that the occurrences of opposites in the experiments are due to habits and customary systems. In some cases it is possible to estimate reasonably what the habit or system in question is and how it developed. Thus *boy*⟶*girl* and *girl*⟶*boy* would be expected to be strong connections because of the juxtaposition of the words and comparison or contrast of the realities in family, school, and social experience. Moreover, when a reality is thought of as one or the other of two such classes, the thought of it as being one of them is to a certain extent

the thought of it as not the other. The thought *boy* is often in part the thought *not girl,* and vice versa. Similarly *hard*⟶*soft,* and *soft*⟶*hard* would be expected to be strong connections first because of usage and second because to think *hard* is in part to think *not soft,* and to think *soft* is in part to think *not hard.* The scale or classification is kept in mind as a *soft–hard* progression or contrast or division, and the thought of one end or compartment of it is precisely the thought of the hard end of the *hard-soft* scale or classification.

If the two opposites have neither been juxtaposed in experience nor been partly constitutive of the thought, each of the other, one does not evoke the other often in the experiments. So *beautiful* evokes *ugly, homely, ill-looking* or the like in 12.4%; *comfort* evokes *discomfort, annoyance, misery, pain, torture,* and the like in only 4.3%. *4* does not evoke *—4* or *1/4,* except in minds of much mathematical experience. So *ja* and *nein* form a little system for Germans, but *ja* and *yes* and *nein* and *no* are the systems for English speakers with little experience of German.

In so far as special juxtaposition in sentences and phrases like *in sickness or health, black and white, hard or soft, hot or cold,* plays a part in forming these connections between opposites, we should expect a somewhat greater strength in the direction of the common usages than in the reverse. Such is the case. We find

black⟶*white*	45.1	*white*⟶*black*	42.9
hot⟶*cold*	40.1	*cold*⟶*hot*	32.7

That frequency and fitness of connection in the past are true causes of the relative strength of the connections within Table 128 is indubitable. That they are the entire causes may be questioned, but the fact that *boy*⟶*girl* occurs over a hundred times as often as *garçon*⟶*fille* (or *girl*); that *joy*⟶*sorrow* occurs twenty times as often as *trouble*⟶*ease,* and eight or ten times as often as *comfort*⟶*discomfort*; that *pro*⟶*con* occurs nearly twice as

often as *con*⟶*pro*, and hundreds of times as often as *ad* ⟶*from*, or *trans*⟶*around*; that *now*⟶*then* occurs fifty times as often as *ocean*⟶*land*, or *religion*⟶*atheism* or *soldier*⟶*civilian* or *decimal*⟶*integer* (or *whole number*), and many similar facts prove that frequency and fitness are real causes.

On the whole, I conclude (1) that if we start with a general tendency for contrariety to direct thought, we find many facts impossible of explanation thereby; (2) that the facts found are explainable by special habits and systems produced by habits; (3) that many of the cases which could conceivably be due to a potency of contrariety *per se*, seem in fact explainable by special habits and habit-systems; (4) that with better insight and fuller information we may expect all cases to be so explained and that the general laws which, acting in very simple ways, cause *Yours* and *Yes* to call up *truly* and *sir*, when acting in more complex and subtle ways, cause them to call up *mine* and *no*.

§ 7. Repetition and reward *versus* transcendent systems

We may now turn to examine the forces of repetition and reward, the adequacy of which seemed questionable in the light of the relative frequencies of *yours*⟶*mine* and *yours* ⟶*truly*, *no*⟶*yes* and *no*⟶*sir*, *good*⟶*bad*, *good*⟶ *morning*, and the like.

The discrepancy is, I think, largely due to the failure so far to consider certain very important connections which are formed with words in the course of hearing and reading. The most frequent and most satisfying connection which a word makes is, as a rule, that with its meaning. When we see or hear *afraid* or *bread* or *cold* or *dear* or *in* or *long*, the usual *sine qua non* for successful progress in our activity is that the word should evoke its meaning. If we read *She was afraid of having no bread and meat*, or *It is a cold day, my dear child, so come in the house*, the connection *afraid*⟶*of* is of trivial importance compared

with the connection *afraid*$\longrightarrow$*meaning of afraid*; the connections *bread*$\longrightarrow$*and* and *cold*$\longrightarrow$*day* are of trivial importance compared with the connections *bread*$\longrightarrow$*meaning of bread* and *cold*$\longrightarrow$*meaning of cold.* In well over nine-tenths of its occurrences in hearing and reading, namely, in all except those in which the word loses its identity in some idiom, or is heard as nonsense, it evokes its meaning. The mental stuff in which the meaning comes we need not now describe. It varies greatly in different individuals for different words.

The history of the experience whereby words get meanings attached to them is what we need to consider first. It is clear. The meaning a word has comes either (A) from the things, qualities, acts, events, and relations with which it has been connected, or (B) from the verbal statements, synonyms, definitions, and the like with which it has been connected. Pictures, diagrams, and other non-verbal representations may for our present purpose be classified under A. Algebraic, numerical, chemical symbols, and the like may be classified under B. Thus the meaning of *bread* is learned partly by its being connected with loaves seen in the kitchen and slices seen and eaten at the table, and partly by hearing *Bread is made of flour. Bread is good for you. Bread is a food. We eat bread. The baker makes bread.*

Without such connections *bread* is a nonsense syllable.

When a person hears or sees a word and has its meaning, he may have it only sufficiently to enable him to fulfill his purpose of the time being. He need not, for example, on hearing *bread* have any image of loaf or slice or taste, or, say, a clear idea *Bread is a food.* He does, however, know somehow, what *bread* means probably by reduced or incipient associative tendencies which originated in the experiences described above and which would, if allowed to act fully, lead him on to representations of *bread* and its qualities, or verbal judgments about it.

The nature of the mental stuff in which these associative

tendencies exist or by which their presence is indicated, in ordinary hearing and reading, is of much less importance to our inquiry than the fact that such associative tendencies do exist.

The meaning of a word is derived originally from its connections with realities and with other words, and is fully realized at any time by permitting these connections to operate. In one form or another, and in greater or less degree, these connections remain attached to the word, especially as heard or seen.*

If a word is seen or heard and a person's mind is set toward reporting the first word "that it suggests" or "that comes to mind," these connections constitutive of meaning will be likely to operate. If one or more of them do operate, the person will think of some thing, quality, act, event, or relation which has frequently and fitly gone with the word or of some verbal expression which gives it meaning. If the former occurs, the person may write the name of the real thing, quality, act, event, or relation as his response, or may proceed further to some associated idea and its name. If the latter occurs, the person may think of a synonym and write it, or of the name of some feature or property that gives meaning, or of the name of the class to which the fact belongs, or the like. In some cases, and this is important, the connections which give a word meaning may lead to the word's opposite. *Long, what does it mean, cold, what does it mean, sweet, what does it mean*—these situations may call up representations, realities, but these can only be named *long, cold,* and *sweet,* and the subject hesitates to name them thus. So the connections leading to *not short, not hot, not sour* and *not bitter,* may determine his response.†

How else can one define long than by thinking of length

* With it spoken or written such connections are weaker, the connections with sequent words being then relatively stronger.

† As stated elsewhere, they have added strength from special habitual sequences.

and its extremities? Only by connections leading to cases of long things, no one of which alone has much strength.

Many of the responses which are reported and which are hardest to explain as habitual sequences in speech or reading or writing are explainable as products of such word-meaning connections. The records for *cold* from 162 educated adults may serve as an illustrative evidence of this. I have arranged them tentatively in groups as shown below. There may well be differences of opinion about the particular assignments of some of the responses, but there can be little doubt that all save the *heat, hot, warm,* and nine others are explainable as the products of either habitual sequences or word-meaning connections. If our explanation of the opposites is valid, the data of the free-association experiment may be regarded as a very strong support to connectionism in general.

Caused by word-meaning connections due to real experiences, or to verbal representations of, or references to, real experiences.
br-r-r-r
catarrh
cough
frost
frozen
ice (16)
ice-cream
like ice
sick (2)
sneeze
snow (7)
winter (20)

Caused by word-meaning connections due to verbal statements and the like.
Alaska
Canada
chilly
disagreeable
discomfort
frigid
icy

Probably caused by word-meaning connections.
heat (3)
hot (46)
warm (25)

Caused by habitual sequences in speech or writing.
air
cream
day
head (3)
meat
shoulder
shower
sweat (2)
water (5)
weather (3)

Caused by phonetic connections.
hold
mold

Caused by connections not known.
fine
hard (2)
H_2O
pain
wet
[no response]

Evidence in support of our hypothesis that the responses which are not due to habitual sequences are due largely to connections between words and their meanings may also be found in the differences between the responses of children and those of adults.

A comparison of the frequencies for one thousand children reported by Woodrow and Lowell ['16, pp. 33-71] with the average of the Kent-Rosanoff and O'Connor results shows the following for the first six words (in alphabetical order) and for the next six which show many opposites in the adult responses.

		Adults	Children
1 afraid	fear	241	14
	dark	82	151
	scared	176½	290
	brave	29	4
	night	11½	51
2 anger	mad	175½	471
	temper	100½	8
	wrath	82½	0
	cross	28½	56
	fight	14	57
3 baby	child	281	172
	infant	135½	20
	small	53	90
	cry	38	119
4 bath	clean	134½	192
	cleanliness	85	1
	wash	107½	143
	water	319	295
5 beautiful	pretty	179	280
	handsome	77½	13
	nice	51	169
	ugly	84½	0
	homely	58½	4
6 bed	sleep	429½	453
	rest	97	17
	soft	40	39
	night	11½	106
7 black	color	96	104
	dark	176½	315
	white	422	27
	dress	16½	63
	dirty	less than 10	42
8 boy	child	65½	45
	girl	414	32
	man	108	61
	male	50½	9
	ball	5½	55
	cap	less than 10	53
	pants	"	63
	play	21	84

		Adults	Children
9 cold	hot	238	12
	ice	82½	84
	warm	181	25
	winter	105½	103
	snow	38	62
	freeze and freezing	not over 28	108
10 dark	light	526½	68
	black	80½	90
	night	191½	416
	afraid	less than 10	49
11 deep	shallow	238	11
	water	123½	154
	sea	90½	21
	down	21½	45
	hole	26	251
	well	47½	154
12 girl	boy	399½	40
	female	73½	22
	woman	80½	8
	dress	21	240
	hair	less than 10	38

The responses by opposites are less than one-tenth as frequent for the children. Responses by the abstract quality which gives or helps to give the word's meaning occur much less often. In place of these the children report what the thing meant by the word does (as in *baby*⟶*cry, anger*⟶*fight, boy*⟶*play, cold*⟶*freeze*), or when and where it is found (as in *bed*⟶*night, black*⟶*dress, dark*⟶*night, dark*⟶*afraid, deep*⟶*hole, deep*⟶*well*), or what concrete earmarks or characteristics it has.

This is just what we should expect if the word-meaning connections were potent influences in both adults and children. In an adult's mind *boy*⟶*meaning of boy* would naturally lead on to *man, male,* (not a) *girl.* In a child's mind *boy*⟶*meaning of boy* would by the same token lead on to *ball, cap, pants, play.*

When word-meaning connections lead on to verbal synonyms we would expect these to differ with maturity just as they do in fact differ. As we pass from adults' responses to children's responses, *afraid*→*scared* rises from 176½ to 290; *baby*→*infant* drops from 135½ to 20; *anger*→*mad* rises from 175½ to 471; *anger*→*temper* drops from 100½ to 8, and *anger*→*wrath* from 82½ to 0; *beautiful*→*pretty* rises from 179 to 280, and *beautiful*→*nice* from 51 to 169, while *beautiful*→*handsome* drops from 77½ to 13, and *beautiful*→ (not) *ugly* drops from 84½ to 0.

The Woodrow-Lowell records permit us to make a test of the hypothesis that the responses by opposites in the free-association test are due partly to connections of habitual concatenations and sequences in speech and writing, but chiefly to the word-meaning connections of hearing and reading. If it is correct, the following should hold good: Let all the responses to eight or ten words amongst adult records, except the opposites, be assigned to (A) habitual concatenations and sequences, (B) word-meaning connections or their outcomes, and (C) other special influences.

Let the responses of children to these same words be assigned similarly. Then, using *a*, *b*, and *c* with the meanings for the children's records which *A*, *B*, and *C* have for the adult's records, and using *D* and *d* for the percent of opposites, $a + b + d$ should equal $A + B + D$, though *D* is very much larger than *d*, the excess of *D* being made up in children by word-meaning connections leading to childish synonyms, concrete features, and symptoms, objects in which the quality in question inheres, and the like.

We have made this test with the first ten words of the Kent-Rosanoff list which have an opposite as response in 25% or more of the cases, and occur also in the Woodrow-Lowell list. These are *black, boy, cold, dark, girl, hard, heavy, high, king,* and *light.* We use our records for adults because they are complete. The details of our assignments,

which we have sought to make entirely impartial, are on file at Teachers College.

The results appear in Table 127. The sum of $A + B + D$ is very nearly that of $a + b + d$, though A is larger than a and D is nearly ten times as large as d. The reader should note that, if our allotments are valid, nearly 95 percent of the responses are explainable by connections formed by repetition and reward in the course of hearing and seeing and using words.

TABLE 127

FREQUENCIES (PER MILLE) OF VARIOUS SORTS OF CONNECTIONS ACCORDING TO OUR CLASSIFICATION OF THE RESPONSES IN THE FREE-ASSOCIATION TEST

	Children					Educated Adults				
	Rhymes	Common Expressions	Meanings (except Opposites)	Opposites	Not Allocated	Rhymes	Common Expressions	Meanings (except Opposites)	Opposites	Not Allocated
black	2	81	827	27	63	6	136	315	469	74
boy	5	105	806	34	50	0	92	255	632	21
cold	6	160	761	39	33	12	117	370	457	43
dark	2	63	780	122	33	6	124	352	481	37
girl	0	165	771	42	22	12	162	175	576	75
heard	5	239	635	67	54	0	281	141	526	52
heavy	1	35	886	54	24	0	193	349	380	78
high	4	69	844	43	40	5	117	292	555	31
king	2	86	796	50	66	5	245	292	388	70
light	5	194	604	116	81	11	198	236	412	43

If we take any other transcendental system, such as a linking by likeness, or by membership in a class or genus, we find the same result from the association-test material. At first thought, certain connections seem to have strength beyond what frequency and fitness could have created, and in agreement with what the transcendental potency or tendency would produce. But more thorough consideration shows that the transcendent potency would not produce what we find, and that frequency and fitness would produce a great deal of it.

Consider, for example, the alleged potency of the variety, species, genus relations. This is made plausible by the following findings: *red*$\rightarrow$*color*, 8.6, *green*$\rightarrow$*color*, 8.0, *blue*$\rightarrow$*color*, 6.5, *six*$\rightarrow$*number*, 12.4, *seven*$\rightarrow$*number*, 9.3, *four*$\rightarrow$*number*, 13.5, *eight*$\rightarrow$*number*, 9.4, *triangle*$\rightarrow$*figure*, 3.1, *Boston*$\rightarrow$*city*, 13.0 *Chicago*$\rightarrow$*city*, 13.6, *Paris*$\rightarrow$*city*, 14.6, *Italy*$\rightarrow$*country*, 12.0, *buttercup*$\rightarrow$*flower*, 42.0, *tulip*$\rightarrow$*flower*, 46.9, *daisy*$\rightarrow$*flower*, 52.1, *bachelor's-button*$\rightarrow$*flower*, 26.0, *i*$\rightarrow$*letter*, 9.3, *t*$\rightarrow$*letter*, 17.3, *b*$\rightarrow$*letter*, 11.5, *u*$\rightarrow$*letter*, 10.9, *butterfly*$\rightarrow$*insect*, 13.6, *mutton*$\rightarrow$*meat*, 18.5, *cabbage*$\rightarrow$*vegetable*, 11.5, *eagle*$\rightarrow$*bird*, 37.0, and *Bible*$\rightarrow$*book*, 31.2.

But it is denied by the following: *baby*$\rightarrow$*human being*, 0.0, *boy*$\rightarrow$*human being*, 0.5, *girl*$\rightarrow$*human being*, *child*$\rightarrow$*human being* or *human*, 0.0, *table*$\rightarrow$*furniture*, 0.6, *bed*$\rightarrow$*furniture*, 0.0, *chair*$\rightarrow$*furniture*, 1.8, *thief*$\rightarrow$*criminal*, 0.6, *cottage*$\rightarrow$*building*, 0.0, *cake*$\rightarrow$*food*, 4.3, *gravy*$\rightarrow$*food*, 4.3, *pie*$\rightarrow$*food*, 5.2, *soup*$\rightarrow$*food*, 5.2, *butter*$\rightarrow$*food*, 0.6, *cabbage*$\rightarrow$*food*, 0.5, *cat*$\rightarrow$*quadruped*, 0, *cow*$\rightarrow$*quadruped*, 0, *dog*$\rightarrow$*quadruped*, 0, *lion*$\rightarrow$*quadruped*, 0, *sheep*$\rightarrow$*quadruped*, 0, *coat*$\rightarrow$*clothing*, 0.6, *collar*$\rightarrow$*clothing*, 0, *hat*$\rightarrow$*clothing*, 1.0, *shoe*$\rightarrow$*clothing*, 1.6, *coat*$\rightarrow$*clothes*, 1.2, *collar*$\rightarrow$*clothes*, 0, *hat*$\rightarrow$*clothes*, 1.0, *shoe*$\rightarrow$*clothes*, 0.5, *square*$\rightarrow$*figure*, 2.1, *square*$\rightarrow$*shape*, 0.0, *triangle*$\rightarrow$*figure*, 3.1, *triangle*$\rightarrow$*shape*, 0.0, *pro*$\rightarrow$*prefix*, 2.5, *con*$\rightarrow$*prefix*, 0.6, *trans*$\rightarrow$*prefix*, 0.5, *ence*$\rightarrow$*suffix*, 3.1, *ment*$\rightarrow$*suffix*, 4.9, *sour*$\rightarrow$*taste*, 1.8, *bitter*$\rightarrow$*taste*, 3.7, *sweet*$\rightarrow$*taste*, 0.0, *salt*$\rightarrow$*taste*, 3.6.

The facts of both lists are better explained as consequences of word-meaning associations.

My explanation of the results of free-association experiments is that the stimulus word has no power beyond that given to it by repetition and reward. Its connections have been established chiefly by hearing and reading on the one hand, and speaking and writing on the other. The former are, in the main, connections from the sound or sight of the

word to more or less of its meaning, including ideas of the real things, qualities, events, and relations with which the word has been experienced and to which it belongs. The latter are in the main connections from the speaking or writing of the word to words spoken or written after it or together with it in a phrase which operates as a unit.

When the meaning comes in verbal form it may be in various patterns such as *S means A*, or *S is B*, or *S has C*, or *S does D*, or *S makes E*, or *S is a F*, or *S is a part of a G*, or *S consists of H*. In such cases, the individual rarely reports the *means, is, has, does,* etc., even though he was aware of it. In many cases he is probably not aware of it, the connections having operated in the form, say of $S \longrightarrow A$ plus an unverbalized sense that *A* is an equivalent for *S*, and this unverbalized sense failing to be impressive under the conditions of the experiment. In many cases, indeed, the history may be more truly stated as past experiences of *S, what does it mean?*$\longrightarrow$*A, S, what is it?*$\longrightarrow$*B, S, what qualities has it?*$\longrightarrow$*C, S, what does it do?*$\longrightarrow$*D*, operating to cause *S think of a word*$\longrightarrow$*A* (or *B* or *C* or *D*) under the conditions of the free-association experiment.

When the meaning comes in the form of non-verbal ideas of real things, qualities, events, and relations with which the stimulus word has been experienced, the subject may complete his task by naming the reality. But he may proceed to some idea associated with the reality and name it. In the very important and frequent case when the reality he thinks of has the stimulus word as its name, he will usually so proceed, since it does not seem fitting to write the stimulus word as a response to itself. For example, on hearing the word *table* many subjects will think of a real table, and proceed to further thought. When the subject does so proceed, some frequent and fitting connection with the perceptions of real tables will often come to mind. In general, the connections made and rewarded by perception may thus share in determining the response in the free-association experiment.

Similarly when the reality is an act or event, the connections with that act or event may share in determining the response.

Besides the hearing-reading connections, mostly with meanings, and the speaking-writing connections, mostly in frequent and fitting expressions, there are, of course, connections made in thought or reflection itself. There are also phonetic connections, notably those productive of rhyming.

Certain special varieties of hearing, reading, speaking, and writing, for example, study, translation, and computation with numbers, produce important connections and systems of connections.

It is possible that the products of all perceptions within the same sense-field are connected over and above expectation by repetition and reward, but this influence upon results of free-association tests is certainly small. It is possible that the organization of original connections and readinesses which justifies us in allotting them to sex behavior, maternal behavior, and the like may modify the connections due to specific original tendencies and to repetition and reward. We are hampered in deciding by insufficient knowledge of what connections and readinesses are original, and of how they are organized. I find no sufficient reasons for ascribing any power over and above that of repetition and reward to any "higher powers" or "forms of thought" or "transcendent systems."

*

TABLE 128

WORDS GIVEN AS RESPONSES TO WORDS FROM THE KENT-ROSANOFF LIST AND TO CERTAIN OTHERS, INCLUDING CERTAIN PREFIXES, SUFFIXES, AND NUMERALS

1 = the stimulus word.
2 to 9 refer to our experiments; 10 to 20 refer to the Kent-Rosanoff and to the O'Connor results.
2 = the commonest response to it.
3 = the frequency of this commonest response (in %).
4 = the next commonest response.
5 = its frequency (in %).
6 = the frequency (in %) of the opposite oftenest given as a response.
7 = the frequency (in %) of the synonym oftenest given as a response.
8 = the opposite oftenest given (unless already entered under 2 or 4).
9 = the synonym oftenest given (unless already entered under 2 or 4).
10 = the same as 2, but for the Rosanoff results.
11 = the frequency of 10 (in thousandths).
12 = the frequency of 10 in the O'Connor results (in thousandths).
13 = the same as 4, but for the Rosanoff results.
14 = the frequency of 13 (in thousandths).
15 = the frequency of 13 in the O'Connor results (in thousandths).
16 = the third response in frequency in the Rosanoff results.
17 = the frequency of 16 (in thousandths).
18 = the frequency of 16 in the O'Connor results (in thousandths).
19 = the frequency (in thousandths) of the opposite oftenest given in the Rosanoff results.
20 = the frequency (in thousandths) of the synonym oftenest given in the Rosanoff results.

(*Table 128 continued on pages 384-391*)

1	2	3	4	5	6	7	8	9
ad	advertisement	15 1	paper	8 3	0 5	7.3	away	to
add	subtract	38 3	number(s)	14 8	38 3	2 5		plus
afraid	fear	23 4	scared	9.9	5 2	9 9	brave	
always	never	26 5	ever	17 3	26 5	17 3		
anger	ire	23 4	rage	14.5				
b	c	25 0	a	13 0				
baby	cry	19 8	boy	15 4	0.0	2 5		infant
bachelor's button	flower	30 9	blue	5.6				
ball	bat	14 6	round	13.0		2 0		sphere
bath	tub	24 5	water	12 0				
beautiful	girl	17 9	ugly	11 7	11 7	3 7		pretty
bed	sleep	44 3	room	4 1				
Bible	book(B)	31 2	God	7 8				
bitter	sweet	62 3	sour	3 7				
black	white	45 1	dark	4 9	45.1	4 9		
blossom	flower	44 3	time	5 2				
blue	sky	18 2	color	13 0				
Boston	Mass.	34.0	beans	17 3				
boy	girl	61 5	lad	3 1	61 5	3 1		
bread	butter	37.0	food	10 4				
butter	bread	24 1	cup	13 6				
buttercup	flower	42 0	yellow	15 4				
butterfly	insect	13 6	wings	11 7				
cabbage	vegetable	11 5	corn beef corned beef	9 4				
cake	eat	18 5	sweet	14 8				
carpet	rug	35 2	floor	11 7				
cat	dog	42 0	rat	11 7				
chair	table	37.7	seat	20 4				
cheese	cream	8 9	mouse	7.3				
Chicago	Illinois	20 4	city	13.6				
child	boy	10 9	baby	9 9	3.1	3 1	man	infant
citizen	man	15 4	United States	9 3	1.2	1.8	alien	citoyen
city	New York (N.Y.)	20 8	town	10 4	9.4	10 4	country	
coat	hat	17.9	vest	4 9		2.5		jacket
cold	hot	32 7	warm	11 1	32 7	0.6		chilly
collar	tie	30 3	white	17 2				
comfort	ease	19 1	chair	9 9	1 8	19.1	discomfort	
command	order	30 9	obey	15 4	15 4	30.9		
con	pro	22 8	with	19.8	22 8	25 3		with against
cone	ice-cream	53 7	ice	4 9				
cool	hot	17 3	warm	10 5	10 5	4.3		cold
cottage	house	24 5	small	10 4				
cow	milk	49.0	animal	7 8				
crooked	straight	35.9	stick	6 8	35.9	1.0		bent
daisy	flower	52 1	chain	4 7				
dark	light	47 5	night	22 8	47 5	1 2		gloom
decimal	point	30 2	fraction(s)	17 9	0 6	4 3	integer	tenth
deep	sea	16 7	water	11.1	9 3	0 6	shallow	profound
doctor	sick	13 6	M.D.	12 4				
dog	cat	51 0	animal	8 9				
dream	sleep	22 4	girl	8 3				
eagle	bird	37 0	nest	7 3				
earth	round	10.4	worm	8 3	1.6	6.2	water	ground
eating	food	18 5	drinking	17 3				
eight	nine	44 3	number	14.6	0.0	0.5		twice-four
ence	pence	13.0	hence	10 4				

10	11	12	13	14	15	16	17	18	19	20
fear	197	285	dark	114	50	scared	106	247	18	106
temper	149	52	mad	121	230	wrath	52	113		
child	239	323	infant	168	103	small	42	64		168
water	339	299	clean	120	149	cleanliness	109	61		
handsome	86	69	pretty	113	245	nice	73	29	66	113
sleep	345	514	rest	132	62	sleeping	41	11		
book	338	405	religion	89	93	holy	57	49		
sweet	305	518	sour	222	180	taste	66	55		
white	339	505	dark	172	181	color	129	63		
flower(s)	540	551	apple	50	49	tree	40	33		
color	256	270	sky	239	178	red	54	80		
girl	319	509	man	104	112	child	86	45	319	7
food	191	220	butter	151	172	eat	148	208		
bread	206	262	milk	101	120	yellow	80	53		
insect	261	196	bird	64	97	pretty	39	31		
vegetable(s)	404	388	plant	48	66	green	44	19		
floor	256	245	rug	163	354	soft	78	59		
table	191	309	seat	127	141	sit	107	118		
butter	136	194	milk	106	107	food	91	89		
baby	193	146	infant	122	94	boy	64	159		
man	278	272	person	64	37	people	41	24	14	
town	258	452	New York	99	8	country	74	31	74	258
warm	166	196	hot	151	325	winter	120	91	166	30
ease	165	247	pleasure	77	33	home	63	40	24	165
obey	230	221	order	171	297	general	43	26	230	171
house	461	549	home	85	106	country	36	10		
light	427	626	night	221	162	black	76	85	427	6
shallow	180	296	water	134	113	ocean	93	56	180	4
physician	213	126	medicine	149	155	sickness	104	131		
sleep	339	453	thought(s)	60	21	vision	48	40		
bird	668	618	fly	46	82	flying	23	12		
ground	166	234	dirt	115	200	clay	71	15	10	166
food	170	252	drinking	166	144	bread	46	18		

1	2	3	4	5	6	7	8	9
foot	hand	14 2	toe	13 0				
four	five	38.0		15 1	0 0	1 5		4
fraction	number(s)	13 5	part	12 5	2 1	12 5	whole	part
fruit	apple(s)	27 2	fly	6 2				
future	past	24 5	time	4 7	24 5			
ganz	whole	12 4	goose	6 2	2 5	16 7	not, nothing	whole, all
garçon	boy	56 7	waiter	10 9	0 5	67 6	fille, girl	
girl	boy	54 3	woman	5.6	54 3	1 8		maid
gravy	soup	21 6	meat	16 7				
green	grass	19 8	red	12 4				
hammer	nail(s)	32 8	tongs	7 8				
hand	foot	17 9	finger(s)	12 4				
hard	soft	49 0	rock	5 2	49 0 2.1	0 5	soft easy	difficult
hat	coat	24 5	head	16 7				
head	hat	15 1	hair	13 5	5 7	2 6	foot	top
health	good	10.9	wealth	10 1	3 1 3 1 2 1	1 6	disease sickness illness	hygiene
heavy	light	37 0	weight	10 9	37.0	0 5		weighty
high	low	54 2	mountain	5 2	54 2	2 1		tall
hot	cold	40 1	stove	8 3	40.1	2 6		warm
house	home	12.4	room	4 3				
hungry	food	15 6	eat	15.1	4 7		full	
i	j	10 5	letter	9 3	8 6	8 0	you	me
ing	sing	11 7	singing	9.3				
Italy	country	12 0	Mussolini	10.9				
joy	sorrow	18 7	happiness	16.7	18.7	16 7		
justice	peace	24.0	law	13 5	1 6	1 6	injustice	fairness
king	queen	35.9	George	6 8		4 1		ruler
lamp	light	49 0	shade	14 1				
late	early	38 3	tardy	9 3	38 3	9.3		
light	dark	34 4	lamp	10 4	34 4	2 1		bright
lion	animal	17 2	tiger	12 5				
long	short	52 1	time	4 7	52 1	0 5		not short
loud	noise	34 6	soft	24.1	24 1	6 2		noisy
maison	house	52 1	French	5 2				
man	woman	50.0	boy	4 9	50 0	1 2		male
memory	test	10 9	mind	9 9	1 0	0.5	forgetfulness	retention
ment	suffix	4 9	meant	4 9				
merci	thanks thank you	55.6	French	7 4				
moon	sun	11 7	night	11.1				
mountain	hill	16 7	high	16.0	9 9	1 2	valley	height
multiply	divide	21.9	add	14.1	21.9	1.0		increase
music	song	11.7	piano	6 8				
mutton	sheep	29 0	meat	18.5				
needle	thread	33 3	sew	14 2				
nein	no	43 2	German	9 4	8 3	43 2	ja, yes	
nicht	night	20 3	not	19 3	3.6	19.3	ja, yes	not
now	then	27.6	never	13.5	27 6	6.2		present
ocean	sea	21.4	water	18.7	0.0	21 4	land	
or	either	15 1	nor	14 1				
oui	yes	61.1	French	4 9	6.2	61.1	non, no	

10	11	12	13	14	15	16	17	18	19	20
hand	185	295	shoe	146	107	walk	106	43		
apple(s)	259	400	vegetable(s)	103	123	eat	62	47		
boy	350	449	female	77	70	woman	61	100	350	13
grass	284	237	color	200	256	blue	46	56		
nail(s)	283	367	tool	69	79	hard	53	47		
foot	204	305	finger(s)	122	222	arm(s)	65	116	367	
soft	367	574	stone	102	34	wood	66	11	17	5
hair	159	163	body	146	152	foot	64	122	64	31
sickness	153	257	strength	112	28	happiness	111	60	9 153 13	2
light	273	468	weight	177	122	iron	70	39	273	22
low	328	515	mountain	157	84	tall	57	70	328	57
home	103	103	building	78	55	barn	74	98		
food	136	194	eat	126	164	thirsty	61	89	9	
happiness	215	236	sorrow	135	221	pleasure	121	100	136	215
peace	143	212	law	74	118	court(s)	66	124	26	21
queen	354	487	ruler	162	106	crown	63	52	2	162
light	650	578	oil	49	9	shade	37	113		
dark	231	415	sun	85	36	lamp	82	113	231	47
animal	326	321	tiger	102	237	beast	67	41		
short	413	573	distance	81	37	length	50	54	413	6
noise	205	161	soft	165	406	noisy	112	76	165	112
woman	394	561	male	99	53	boy	44	57	394	99
mind	138	148	thought(s)	109	100	good	68	62	37	5
light	231	175	star(s)	125	123	sun	120	194		
high	246	171	hill	184	364	valley	90	107	90	75
piano	180	205	sound	95	85	song	68	125		
meat	257	190	sheep	204	215	lamb	121	276		
thread	160	280	pin(s)	158	174	sharp	152	130		
water	427	429	deep	87	37	sea	75	223	8	75

1	2	3	4	5	6	7	8	9
Paris	France	38 0	city	14 6				
patter	rain	24 5	pitter	22 4				
pie	eat	20 8	apple	17 7				
priest	church	22.4	Catholic	7.3	0 0	4 1 4 7	nun	minister preacher
pro	con	43 2	for	17 9	43 2	17 9		
quiet	loud	12 4	still	9 3	12 4	9 3		
red	blue	19 8	green	11 7				
religion	church	12 0	Bible	6 2	0 5	4 7	atheism	faith
river	water	15 4	Hudson	9 9	1 2	7 4	rivulet	stream
rough	smooth	30 2	ready	14 2	30 2	0 6		stormy
rumble	seat	35 9	noise	18 2				
salt	water	17 7	sugar	11 5				
scissors	cut	55 6	shears	6 2				
sehr	very	21 0	German	9 3	0 6	21 0	little	
seven	eight	32 7	eleven	22 8	0 0	0 6		7
sheep	wool	14 2	animal	8 6				
shoe	foot	17 2	lace	16 7				
short	long	42 6	tall	14 2	66 8	3.1	long tall	little small
sickness	health	13 0	ill	12 4	16 0	19 1	health well	illness ill
six	seven	43 8	number(s)	13 0	0 0	0 6		half-dozen
sleep	rest	16 0	bed	16 0	4 3	1 2	wake	slumber
slow	fast	48 8	quick	4 9	53 7	1 2	fast quick	leisurely dull
smooth	rough	34 0	soft	9 9	34 0	3 1		even
soft	hard	38 3	bed	5 6	38 3	1 2		mushy
soldier	war	18 7	sailor	11 5	0 5	1 0	civilian	fighter
soup	spoon	7 3	eat	5.7				
sour	sweet	42.0	grapes	13 6	42 0	0.5		acid
spider	web	58 0	fly	13.6				
square	round	21 9	circle	12 5				
stem	flower	27 6	leaf	14.1	1 6	2 1	stem	branch
stomach	ache	27 6	trouble	7.3				
stove	hot	23 4	black	10 4	0 0	1.0	refrigerator	heater
street	car	7 8	avenue	6.8		6.8		
sweet	sour	27 8	bitter	21 0	27.8		(candy 9 9	nice 0 6)
swift	fast	23 4	slow	20 3	20 3	23.4		
t	letter	17 3	s	15 4				
table	chair	45 7	food	6 2				
thief	robber	18 5	steal	13 0	3 1	18 5	police(man)	
thirsty	drink	30 7	water	27 1		8.9		dry
thunder	lightning	27 8	storm	22.2				
tobacco	smoke	34 6	pipe	11 1				
trans	across	31 2	Atlantic	25 0	0 0	31 2		
triangle	square	24 7	geometry	24 1	4 9	1 8	circle	three-cornered
trouble	sorrow	7 8	worry	5 2	1.0	0.5	ease	distress
tulip	flower	46 9	buttercup	5 6				
u	you	18 7	v	15.6				
warm	cold	26 0	hot	14 1	26 0	14.1		
while	away	7 1	time	6 1		5.1		during
whiskey	drink	18 2	prohibition	10.4				
whistle	blow	11 1	loud	10 5				
white	black	42.9	color	6.3	42.9	3.2		colorless clean

10	11	12	13	14	15	16	17	18	19	20
minister	178	232	church	166	207	man	75	39	12	178 35
still	136	74	noisy	113	117	rest	68	30	113	136
color	245	228	blue	99	87	white	97	164		
church	161	223	Catholic	56	39	Bible	52	99	2	47
water	393	324	stream	117	224	lake	65	61		
smooth	346	491	uneven	38	44	hard	38	65	346	38
pepper	142	213	sugar	88	110	taste	87	57		
cut	347	482	sharp	190	116	cutting	114	63		
animal	225	188	lamb(s)	187	241	wool	143	149		
long	279	354	tall	163	284	small	136	90	279	136
health	142	168	death	115	166	illness	71	85	182	119
rest	300	225	awake	94	140	bed	75	118	60	20
fast	316	604	easy	63	44	snail	62	20	372	7
rough	277	416	soft	79	63	glass	56	46	277	30
hard	365	548	pillow	53	42	easy	34	38	365	12
man	189	152	army	137	181	war	94	73	3	12
sweet	349	570	vinegar	91	38	lemon	78	28	349	23
insect	276	232	web	188	340	fly	136	112		
round	250	425	block	71	68	table	47	9		
flower	259	279	plant	74	78	pipe	70	84		
food	102	94	body	99	123	intestine(s)	60	98		
fire	217	157	heat	213	215	hot	86	133		
road	91	124	city	82	86	walk	78	61		63
sour	301	441	sugar	224	157	candy	82	84	301	(82, 6)
fast	222	414	slow	190	225	quick	117	15	190	222
chair	267	333	wood	76	84	furniture	75	16		
steal	212	237	robber	126	190	burglar	118	120	12	126
water	341	273	dry	218	219	drink	206	305		218
smoke	387	583	smoking	98	36	pipe	69	65		
sorrow	202	111	worry	65	58	sickness	47	55	4	7
drink	232	361	liquor	70	94	alcohol	50	33		
noise	173	205	sound	103	44	blow	95	84		
black	308	522	color	170	103	now	91	71	308	

1	2	3	4	5	6	7	8	9
window	pane	27 2	glass	14 2				
wish	desire	19 8	want	8 0	0 0	19 8		
woman	man	51 8	girl	3 1	51 8	1 8		female
working	man	16 1	hard	14 6	2.1	2 6	loafing	labor
yellow	color	12.5	green	10 9				

10	11	12	13	14	15	16	17	18	19	20
glass	316	287	light	186	87	pane	82	248		
desire	197	266	want	66	97	hope	51	100	1	197
man	292	459	female	134	97	girl	59	74	292	134
labor	147	153	hard	105	93	busy	51	15	5	147
color	301	330	white	70	85	orange	47	32		

CHAPTER XV

Desires, Purposes, Interests, and Motives

The connection which any situation makes depends upon the person in whom it is made—upon the general nature which he has and the particular conditions in which he is at the time. When we speak of the strength of a connection as the probability that a certain situation, S, will evoke a certain response, R, in a certain person, P, we assume a certain condition in P. The probability will differ with certain variations in P. Estimates of change in one part of P, to wit, in a certain connection's strength, are made on the assumption that the rest of P does not vary in ways that disturb that connection.

To represent human nature and behavior fully we should, for example, replace a statement that S_{46815} will evoke R_{97326} by a long series to the effect that:

S_{46815}	in mental set	264	will	evoke	R_{97326a}
"	"	167	"	"	R_{97326b}
"	"	275	"	"	R_{219453}
"	"	318	"	"	R_{687110}

etc., etc.

An important fraction of the mind's set at any moment is due to the activities of the preceding seconds or minutes. If one is doing an errand, his steps are guided at any given point by traces of the purpose and plan or directions which started him on the errand. If one is reading a chapter, his ideas from any sentence are determined by traces of the meaning so far. If one is writing a letter, the recipient, the purpose, and the content up to the point reached all share in determining what the next sentence shall be. Sometimes this living past is like a silent partner in a busi-

ness doing nothing so long as all is well, but ready to protect or aid when an emergency arises. Sometimes it is a very active partner influencing each step taken. But always it is there as one of the factors which make the connection system of man one of the most complicated organizations of forces in the world.

A metaphysician could argue that every connection is (1) between some external state of affairs and some total status of the person, or (2) between some one total status of the person and the sequent status, or (3) between external state of affairs plus total status of the person and sequent status of the latter or of both. However true this may be, it is a useless and harmful habit to treat persons as unanalyzable wholes when one is studying the fundamentals of behavior and learning. For such study we need to abstract certain particular connections from the total flow of life of which they are parts.

We do need, however, to use an "other things being equal" proviso in statements about such abstracted parts of behavior and learning, and to remember that the permanent or the temporary status or "set" of the person may be very potent.

Evidence of the influence of mental sets upon learning may be found in any field of behavior. They appear throughout the work of Ach, Bühler, Messer, and other students of what happens in thinking. They form a large part of the facts brought forth as arguments against a too narrow connectionism.

Van der Veldt ['28] had his subjects learn in two sorts of series. In SS the subject learned the position of a light on a keyboard by indirect vision only. In SM the subject moved his hand to the place where the light was, or to a place corresponding thereto. When the subjects have a synthetic schema for a word and consequently show precisely the place corresponding to a syllable which appears in this word, it very often happens that they do not find the place corresponding to this same syllable when it is a part

of another word which they have not yet learned synthetically [p. 115]. A part in the whole is then a very different thing from a part detached from its whole [p. 121]. If two series, SM and SS, have been learned so that the subject can designate quickly and accurately the place of the light corresponding to each syllable of each word in each series, and if then a "mixed series" consisting of words from both SM and SS is presented, the subject has difficulty. He takes a longer time and makes more errors.

Much of the argumentative ammunition used by Gestaltists against associationists consists of cases where *A* in one set produces a total result differing from *A* in another different set.*

Students of animal learning are explicitly recognizing that the set of the animal is potent in determining what he will do and what will satisfy or annoy him, and are measuring the influence of food given as a reward to animals who are very hungry and slightly hungry, respectively, and the like. Students of maze-running are paying more heed to the interest rats have in exploring new places as a disturbing factor.

A very interesting case of the importance of the mental set in which a connection is made is found in the facts brought forward by Dunlap ['28] showing that the repetition of a connection with emphatic awareness that it is wrong, and clear intent to avoid it in the future may, under certain conditions, aid in its abolition. Dunlap writes:

"The first opportunity which occurred for the testing of this method lay in an idiosyncrasy of my own in typewriting. For some years I have been annoyed, when typing rapidly, by an occasional transposition of the letters of a word, the word 'the' being especially troublesome, so that in reading over a manuscript of my own typing I would sometimes find two, three or more of these transpositions

* It would be equally appropriate as an argument to be used by associationists against certain Gestaltist doctrines.

into 'hte.' Several times I have attempted, by careful practice, to train myself out of the habit. The fact that in the majority of cases I actually wrote 'the' exchanging it for 'hte' only in a minority of cases and when typing rapidly, in itself indicates the futility of increased repetition of the 'right' spelling.

"On the basis of the neutral postulate, I now proceeded to try the typing of 'hte' voluntarily, as a means of destroying it. I set to work deliberately and wrote about a half page, single spaced, of the 'hte' combination, with the futuric thought that this was a 'word' that I would *not* write in the future (unless deliberately and voluntarily). Somewhat over a week later, I followed this with a second 'practice period,' writing less than a third of a page. This was over three months ago. Since that time I have typed many pages, some rapidly, but have not found on reading them over a single case of 'hte'! This may sound too easy to be true, but as a matter of fact a long standing and troublesome habit has disappeared.

"Having just changed from driving a Ford to operating a gear-shift car, certain minor vices of technique, such as a tendency to step on the accelerator, when meaning to apply the brake, manifested themselves. The application of the catharsis method seems to have overcome these faults very quickly. Such trials on myself have, of course, no scientific value, but served merely as encouragement in the application to more critical cases.

"The application of the method to speech defects offers an interesting field. In the case of stammerers, the vital point of proceeding here is to study the specific type of stammering and then induce the patient to reproduce voluntarily his characteristic verbal performance, criticizing and assisting him until his voluntary stammering is as nearly as possible like his involuntary. From that point on, the technique is complicated, and we do not expect to have it perfected until many cases have been experimentally subjected to it. In the meantime, the results even with the

crude preliminary method are very favorable.'' ['28, pp. 4 f.]*

Holsopple and Vanouse ['29] give additional evidence showing that stenographers who misspelled words in typing which they could spell correctly orally profited greatly by typing the erroneous spellings (eight lines of each).

Whatever be the cause of the reduction of the tendency by its exercise, the repetition of these undesirable connections in error in the set arranged by Dunlap is very different in nature and consequences from the inadvertent repetition of these same connections.

Among the notable features in the mental set or adjustment are wants, cravings, desires, purposes, interests, motives, ''drives,'' and propensities, and whatever other varieties of appetitive facts the reader may wish to name. These wants, desires, purposes, and the like are of special importance in life and learning. They put certain responses and connections into the state of readiness; among *n* connections equally strong leading from A, those which lead from a certain desire or purpose also will be more likely than the others to be evoked by A plus that desire; they fix criteria whereby, in trial responses, certain ones are selected; they decide which after-effects will satisfy and which will annoy, and to what degree. They deserve extensive and thorough study. They are forces which direct or rule or coöperate with repetition and reward and punishment in learning. They are in a sense more fundamental forces than repetition and reward. They developed earlier in the evolution of animal life; and they appear earlier in the human individual. The responses which man makes and the connections which repetition and reward make in him are made in their service.

We need to know what the original instinctive basis of

* I suggest that the elevation of the situation and response concerned from a relatively uncontrolled status to one where the response is available to do or to avoid at will rather than by inadvertence, may be a part of the causation of the change.

desires, interests, motives, and purposes of man is, how and why they change, how far they can be made available so that a person can summon a want or desire or purpose at will, as he can now summon certain ideas and acts, how they depend upon states of the internal organs, what the amount, rate, and limit of improvement is in these appetitive or conative functions, how permanent changes in them are made, how they are organized and related, how changes in any one of them influence the others, what differences in them characterize human individuals, and how these individual differences are caused.

We have not made new observations or experiments concerning any of these questions, because time and facilities were lacking. It seems highly probable that changes in emotions, interests, wants, purposes, and the like are due to the same forces of belonging, frequency, after-effects, readiness, identifiability, availability, partial activity, coöperation, and system which have been found to be active in changing ideas and acts, and that all the findings of this volume can and should be applied to the learning of interests, attitudes, and ideals. But it will be safer to check this by experiments *ad hoc*.

Learning in the case of wants, interests, and purposes is important not only because they are primary but also because they are ubiquitous and pervasive. The area of behavior in which outside stimuli or inner habits produce results in a person irrespective of his wants, interests, and purposes is relatively small. Even when one seems most at the mercy of the environment, his mind is often picking and choosing; even when the most established routines are operating, there is often supervision by a purpose, which is quick to display its power if something goes wrong. Also, the amount of such drifting and such automatism has been overestimated. Men and animals are usually, whether at work or at play, set to be or do or have something or to avoid or change some unwelcome status.

A large percentage of the states of affairs which are sat-

isfying or annoying are so not because they contain emphatic sensory pleasures or pains, or because they bring general joy, contentment, depression, irritation, or the like to the mind as a whole, but because they satisfy or thwart some particular purpose. The appearance of a satisfaction or annoyance is, then, very often proof of the existence of a purpose. There are two important cases of this. First, multiple response or varied reaction usually implies either the action of a present annoyer and a purpose or desire of the creature to get rid of it, or the equally real action of the absence of a satisfier, that is, of an annoying lack. In the latter case, the creature may identify the lack and definitely desire a certain outcome, or he may be moved only by a more or less blind craving or restlessness. Both behaviors are purposive in the broad sense that inner wants influence what the animal does and what he learns. Second, in the uninhibited, direct, fluent progress of thought or action, as in eating one's breakfast, walking to one's office, reading a chapter which offers no difficulty, or jotting down ready answers to a dozen questions, there may be a steady series of what we have called *O.K.* reactions or *Yes* reactions. The spoon fills with oatmeal, *Right.* The oatmeal is safely deposited in the mouth, *Right.* It is swallowed or Fletcherized according to our custom, *Right.* The meaning of sentence 1 is apprehended, *Right.* These satisfactions are so mild that psychologists have often not considered them satisfactions. But the states of affairs concerned are surely such as, given the mental set in question, the mind "does nothing to avoid, often doing such things as attain and preserve them," and satisfactions may be as real when mild as when intense. We do not assert that there always is such a series or that in cases where such a series does appear, it is complete. The behavior may go on with absolute neutrality in spots or, more rarely, altogether. But a certain moderate degree of acceptability seems to be often attached to fluent, successful thought or action.

Both the so-called *random* activities in *trial and error*

behavior and the so-called *automatic* activities in uninterrupted successes may then be fundamentally purposive.

Much of the discussion of purposes in learning consists of assertions that they operate and denials that frequent association alone or association guided exclusively by pleasure and pain can adequately explain learning. This is all true, but not very profitable. There is no conflict between a reasonable connectionism and a reasonable purposivism.

Van der Veldt, following Michotte, has said that "The actual intent of the subject is infinitely more important than all the rest of the situation." ['28, p. 334.] If we temper the statement by replacing "infinitely" by "often" it is true; but it is equally true that a man can do only what his fund of connections with the situation, including the intent or desire, dictates. I can, by general set of mind to give a wrong answer, think *five* in response to $2 \times 2 = ?$, or, by decision to respond by rhymes, think *wood* in response to *good*. But I cannot, by any set or desire think of the Chinese words for 2×2 or provide a rhyme for *Heliogabalus*. My fund of connections lacks the requisite ones.

No sensible connectionist supposes that a man's mind is utterly subservient to the connections leading from the external stimulus of the moment. But no sensible critic of connectionism should suppose that a man's mind can fulfill its purposes and attain its desires by any other way than the operation of its fund of connections.

It used to be customary for psychologists to think of thought or action as the work of a ruling self using as its tools the more or less machine-like processes of perceptions, memories, habits, etc. And this is, in a rough way, true to fact. The organization of purposes, desires, tastes, points of view, and the like which a self is does issue orders which such connections as are involved in reading, writing, arithmetic, singing, table-manners, and the like do execute. It does accept or reject or amend the execution of the orders which it issues.

When a man is reading a book, or doing multiplication, or cleaning his teeth, or giving words in an association test, he is a self connecting words with their meanings, a self connecting numbers with their products, a self pushing a brush back and forth in a familiar series of movements, a self permitting words to evoke other words more or less freely. There is no great harm, perhaps no harm at all, in such an analysis of a man into an operating self and means through which it operates, provided we do not use it as an excuse for abandoning science. If we proceed to investigate such selves, to study how they originate, what they are made of, and how they can be changed, to test the effects of various forces applied to them, and in general to treat them as facts of nature, to be understood and managed as we understand and manage electric currents or hybrid-plants, the separation of selves from other mental facts which they use and dominate will find a cure for whatever defects it may have. But if such selves are accepted as unexplained principles, mystical forces which are above nature, agents whose acts are inscrutable, they are not only useless but even harmful in science.

What we need in the case of wants, interests, drives, attitudes, purposes, and ideals is not the reiteration of facts which should be obvious to any broad-minded observer (not more chapters like this, for example), and certainly not sermons on their importance, or disputes about their importance in comparison with other forces in life and learning, but more facts about what they are and what they do, and just how they do it.

CHAPTER XVI

Associative Shifting and the Conditional Reflex

It has long been known that a response connected with a certain situation may be made even though the situation is not present in its entirety. "To any new situation man responds as he would to some situation like it, or like some element of it. In default of any bonds with it itself, bonds that he has acquired with situations resembling it, act. . . . A new situation, *a b c d e f g h i j*, is responded to as *abcdelmnop* (or *abcdefqrstu*, or *fghiabyd*, or the like) which has an original or learned response fitted to it, would be." [Thorndike, '13a, pp. 28 f.] This fact serves as a basis for the even better known fact of Associative Shifting that, "Starting with response X made to *ab cde* we may successively drop certain elements and add others, until the response is bound to *fghij*, to which perhaps it could never otherwise have become connected. Theoretically, the formula of progress, from *abcde* to *abcdef* to *abcfg* to *abfgh* to *afghi* to *fghij*, might result in attaching any response whatever to any situation whatever, provided only that we arranged affairs so that at every step the response X was more satisfying in its consequences than balking or doing anything else that the person could do. And the actual extent of associative shifting verifies this theoretical expectation" [pp. 30 f.].

The connection of X with B, by virtue of connecting it first with A + B and then omitting A, is the simplest case of associative shifting.

The primary assertion of Pavlov was that such connection of X with B, of which it was at first not a consequence, could be made *via* connection with A *even when X was a reflex response*, such as had been supposed to be un-

modifiable in its attachments. The importance of this assertion is not that, if true, it proves the fact or law of associative shifting. That fact was well known and demonstrable by abundant evidence. It would be true of responses with modifiable attachments even if it were not true of the salivary reflex. It is proved daily by horses that stop when you say "Whoa," babies who smile at the sight of food, and by most of us in our thoughts and actions with symbols of all sorts.

The importance of the work of Pavlov and his pupils does not lie in the fact that a response, X, is connected with B by way of A→X and AB→X, but in the particular circumstances of this shift and in various features or characteristics observed in the B→X connection, or by means of it. This has not been understood by some psychologists who have used the term conditioned (properly conditional, the Russian word being *ooslovny*) for any connection derived by associate shifting or even for any learned connection, and have applied the features of the conditional or secondary connections with a reflex response described by Pavlov, to connections in general.

The contribution of Pavlov and its significance for the psychology and physiology of learning may best be understood by considering in some detail the differences between the shifting in the formation of a conditional reflex and the shifting in ordinary learning.

1. In ordinary learning by associative shifting the response X, made first to A, then to AB, then to B, belongs to B. At least, such belonging is a possibility. Thus in a cat which comes first to saucer of milk, then to saucer of milk plus call of "Here Kitty, Kitty," the approach may, and probably does, belong to the sound. In the person who sees a picture of a dog labelled *chien* and says *dog, dog* surely belongs to the *chien* as well as to the picture.

In the conditional reflex this is not so surely the case. The formation of a connection between increased flow of saliva and the presence of food in the mouth plus the sound

of a bell does not seem to require that the increased flow of saliva belong to the sound of the bell. The writer is personally of the opinion that it does, directly or *via* belonging to muscular contraction or excitement or some other intermediary. But Pavlov and his followers seem rather to regard the time relations alone as adequate.

2. In ordinary associative shifting the time relations of A and B do not seem to be of great importance so long as the response belongs to the B in AB as well as to the A. If you say *Whoa Whoa Whoa Whoa* and pull on the reins, it probably does not matter much whether you pull at the second or third or fourth *Whoa* except for the greater impressiveness attached to the first term by the extra repetitions. If a person responds to a picture and its name in French by its name in English, it matters little whether he looks at the French word first or the picture first.

In forming a conditional reflex the proper time relations are imperative. The B *must* come ahead of the A, not after it. $B \longrightarrow B \longrightarrow B \longrightarrow B \longrightarrow A + B$ (i.e., B and A combined) is the approved relation. $B \longrightarrow B \longrightarrow B \longrightarrow B \longrightarrow A$ is perhaps workable. But $A \longrightarrow B$ or $A \longrightarrow B \longrightarrow B$ or $A \longrightarrow B \longrightarrow B \longrightarrow B$ are useless; and $B \longrightarrow A + B \longrightarrow A \longrightarrow B \longrightarrow B \longrightarrow A \longrightarrow B \longrightarrow B$, and the like are not recommended.

3. In ordinary associative shifting the attachment of X to B is usually slow unless it is rewarded, and often is slow even with the aid of reward. Thus in teaching a dog to stand on his hind legs at the word *beg* by saying it (B) while holding up a titbit (A) to which he responds by standing on his hind legs, many repetitions are usually necessary, even though we use reward. In the case of reflexes like salivating, or the peculiar involuntary jerk of the leg which follows an electric shock on the shin, we should expect the learning by ordinary methods of associative shifting to be extremely slow, because they are so "unavailable."

In forming a conditional reflex very, very few presentations of B and A are required. After a very few, B evokes X with substantial perfection.

4. In ordinary associative shifting it is often desirable to change the situation rather gradually. We do not usually change from $A \longrightarrow X$ to $A + B \longrightarrow X$ by simply putting B along with A, or before A and overlapping on it, and then suddenly dropping A out. Our procedure is more like Scheme II than Scheme I.

Scheme I	*Scheme II*
1. $A \rightarrow X$	1. $A \rightarrow X$
2. $A + B \rightarrow X$	2. A plus so much B as does not prevent the X response. More than a little B usually does prevent it.
3. B	3. A reduced or weakened a little, plus B slightly increased, still with great care not to prevent X.
	4, 5, 6, etc. Continued reductions of A and increases of B until at last pure B alone evokes X.

In the connection of the salivary reflex with sounds, sights, touches, and the like, even when the connection is long in forming, such elaborate care not to lose X as a response to the mixture is not taken. If there is danger of losing it, A is applied alone to restore it. This would be a very risky thing to do in ordinary associative shifting, as the person would be likely, as a result of it, to revert to the tendency to give X only in response to A.

5. In ordinary associative shifting we rely largely on reward, making the states of the organism following $A + B \longrightarrow X$ and $B \longrightarrow X$ and belonging thereto as satisfying as we can. So an infant taught to urinate when held in a certain position at a certain place (B) is not only held there at times when the A stimulus is likely to be strong, but is rewarded when he does so respond to A + B or to B. The child who is being taught his numerals by being led to respond to : . : *5* or ||||| *5* and then to *5* alone by saying *five* is rewarded when he does so rather than giggles or sulks.

In forming a conditional reflex, reward may occasionally play a part, as when food (A) does come to $B \longrightarrow B \longrightarrow B$

$\longrightarrow$B + A after the animal responds to B by X in case he does so, and so may strengthen B$\longrightarrow$X. But when A is acid in the mouth instead of food, or when A is an electric shock as in the technique of Beritoff, Liddell, and others who use the flexion reflex or withdrawal reflex, reward, if it comes at all, can only be in the ending of some unpleasant state of suspense or tension or the like. There is no intention of the experimenter to reward A + B$\longrightarrow$X or B$\longrightarrow$X, and whatever rewards are attached to them are by inadvertence.

6. In ordinary associative shifting no conditions are required over and above those required for learning of any sort. A reasonable freedom from excitement, disturbance, fear, and the like is all that is necessary. One can teach a dog to beg, or a kitten to come at call, or a child to open his mouth at command without the special and elaborate restriction of all outside stimuli save the A and the B which the connection of a conditional reflex with the new stimulus requires.

In forming a conditional reflex, greater restrictions of the animal are customary, and extreme restriction of the stimuli is, according to Pavlov, imperative. He writes:

"It was thought at the beginning of our research that it would be sufficient to isolate the experimenter in the research chamber with the dog on its stand, and to refuse admission to anyone else during the course of an experiment. But this precaution was found to be wholly inadequate, since the experimenter, however still he might try to be, was himself a constant source of a large number of stimuli. His slightest movements—blinking of the eyelids or movement of the eyes, posture, respiration, and so on—all acted as stimuli which, falling upon the dog, were sufficient to vitiate the experiments by making exact interpretation of the result extremely difficult. In order to exclude this undue influence on the part of the experimenter as far as possible, he had to be stationed outside the room in which the dog was placed, and even this precaution proved unsuc-

cessful in laboratories not specially designed for the study of these particular reflexes. The environment of the animal, even when shut up by itself in a room, is perpetually changing. Footfalls of a passer-by, chance conversations in neighboring rooms, slamming of a door or vibration from a passing van, street-cries, even shadows cast through the windows into the room, any of these casual uncontrolled stimuli falling upon the receptors of the dog set up a disturbance in the cerebral hemispheres and vitiate the experiments. To get over all these disturbing factors a special laboratory was built at the Institute of Experimental Medicine in Petrograd, the funds being provided by a keen and public-spirited Moscow business man. The primary task was the protection of the dogs from uncontrolled extraneous stimuli, and this was effected by surrounding the building with an isolated trench and employing other special structural devices. Inside the building all the research rooms (four to each floor) were isolated from one another by a cross-shaped corridor; the top and ground floors, where these rooms were situated, were separated by an intermediate floor. Each research room was carefully partitioned by the use of soundproof materials into two compartments—one for the animal, the other for the experimenter.'' ['27, pp. 20f.]

7. In ordinary associative shifting we find an animal connecting a large number of different X's with a large number of different B's *via* a large number of A's. A dog or cat makes scores or hundreds of such, a little child makes thousands.

In the formation of conditional reflexes in the laboratory, we have an animal connecting a single X, increased flow of saliva, or a peculiar protective reflex or the like, with several B's *via* a single A. The animal has, so to speak, always one problem; for example, to salivate or not to salivate. This may well put the salivary reflex in a peculiar state of excitability.

8. In ordinary associative shifting, the new connection,

once acquired, behaves like any learned connection, being strengthened by repetition and reward and weakened by lapse of time. But if the B⟶X connection is a conditional reflex formed by the well-known technique used to establish such, it is extinguished (i.e., weakened for the time being) very rapidly by repetition at short intervals.*

This weakening for the time being by repetition is somewhat like what happens to connections deprived of their satisfying after-effects (as when a child ceases hitting a drum that does not sound or reaching for a toy it cannot grasp), but it is very unlike what happens in ordinary learning.

9. With the lapse of time, connections formed by ordinary

* For the convenience of some readers I quote Pavlov's statement and illustration.

"In testing the reflex the metronome is sounded for thirty seconds during which the secretion of saliva is measured in drops, and at the same time the interval between the beginning of the stimulus and the beginning of the salivary secretion is recorded. This interval is customarily called the latent period, although, as will be seen later, some other term might more usefully have been employed. Stimulation by the metronome is not followed in this particular experiment by feeding, i.e., contrary to our usual routine the conditioned reflex is not reinforced. The stimulus of the metronome is repeated during periods of thirty seconds at intervals of two minutes. The following results are obtained:

Latent period in seconds	*Secretion of saliva in drops during thirty seconds*
3	10
7	7
5	8
4	5
5	7
9	4
13	3

. . . "If the experiment had been pushed further, there would have come a stage when the reflex would entirely disappear. This phenomenon of a rapid and more or less smoothly progressive weakening of the reflex to a conditioned stimulus which is repeated a number of times without reinforcement may appropriately be termed *experimental extinction of conditioned reflexes.* Such a term has the advantage that it does not imply any hypothesis as to the exact mechanism by which the phenomenon is brought about." ['27, pp. 48 f.]

associative shifting lose strength just as learned connections in general do.

Conditional reflexes, on the contrary, are restored from the temporary weakness or extinction by the mere lapse of time.

There are other characteristics of conditional reflexes which are not found in connections in general, as follows:

10. The temporary extinction of the B⟶X connection by the repetition of B tends to extinguish also any other conditional reflex, C⟶X, D⟶X, E⟶X, etc. This is as if weakening the tendency to *cheval*⟶*horse* weakened also the tendency to *Pferd*⟶*horse*, or *equus*⟶*horse*.

11. Suppose that a conditional reflex B⟶X has been formed from the unconditional A⟶X and that B + C is presented, with no reintroduction of A. At first B + C evokes X, but with repetition B + C loses that potency, though B alone retains it. This occurs when B and C overlap in time. But if C is presented first and removed as soon as B begins to act, B + C does not lose the potency it has by virtue of the inclusion of B, but the animal is made restless. If B follows C in B + C by an interval of ten seconds or so, the addition of C does not weaken the potency of B, and itself acquires the power to evoke X.

This is as if you learned to say *63* whenever you are asked *9 × 7 = what?* Then occasionally a buzzer is sounded and while it is still sounding, you are asked *9 × 7 = what?* and gradually lose the tendency to say *63*, though if the experimenter says *9 × 7 = what?* without the buzzer you still say *63*. But these occurrences take place only if the *9 × 7 = what?* comes while the buzzer is ringing. If it comes just after the buzzer stops, you don't lose the tendency to say *63* so rapidly, but you get fidgety. If ten seconds intervene between the buzzer and the *9 × 7 = what?*, you do not lose the tendency at all, and you acquire a second tendency, namely, to say *63* twice: once when you hear the buzzer, and once when you hear *9 × 7 = what?*

12. If a "delayed" conditional reflex, that is, a connec-

tion between B and X with a specified length of time between them, is established, the appearance of a new stimulus during the interval will evoke X. [See Pavlov, '27, p. 93.]

This is as if a kitten learned to wait two minutes after you said, "Pull," and then pull a loop, and would then, if you patted it or rang a bell or the like in the interval, at once pull the loop. It would be very hard to teach a kitten to so time its response, and if it did learn to do so, the intrusion of a stimulus during the interval would be more likely to distract it from its task than to set off the performance of it. The arousal of a delayed conditional reflex by any stimulus is one of several lines of evidence indicating that the response, X, is or becomes extremely excitable or "ready" under the conditions of the establishment of it as a conditional reflex.

We are much indebted to the Russian physiologists and psychologists who have studied the phenomena of conditional reflexes. The facts are of very great importance. The use of the facts to explore and explain excitability, inhibition, irradiation, induction, and the like has been and will be of unquestioned service. So also will their use to explore and explain learning. But in the latter use they should be considered along with all the other known facts.

There is difficulty in explaining the phenomena of conditional reflexes by the general principles of learning. Belonging and after-effect, which are the main forces in ordinary learning, do not appear at all clearly or emphatically in C-R learning. Mere sequence, which is weak in ordinary learning, is very powerful in C-R learning. Availability of the response is required for rapid formation of connections in ordinary learning, but in C-R learning an extremely unavailable response forms connections with great rapidity.

There is greater difficulty in explaining the phenomena of learning in general as extensions and complications of the processes displayed in the establishment of a conditional reflex. The discrepancies between C-R learning and

the fraction of ordinary learning most like it, associative shifting, are many and important, as has been shown above. The conditional reflex has certain special characteristics which a connection formed by ordinary associative shifting lacks altogether or shows in a much less marked degree. The latter seems the more general and fundamental. But associative shifting itself is less general and primitive than learning by the selection of one response from several made to the same situation.

We have then three important questions about the phenomena of conditional reflexes in relation to learning in general.

1. Are these phenomena general? Does the sequence B⟶B⟶B⟶B + A, if A is already connected with X, always form the connection, B⟶X, other things being equal?
2. Are these phenomena the primitive forms of learning in general, the *anlage* or *archetype* of associative shifting, learning by trial and success, and all else?
3. How are the two sets of facts to be harmonized?

The third question is better phrased as a group of three.

3. (*a*) Are these phenomena really at variance with the facts concerning the unimportance of mere sequence without belonging, and the weakness of repetition without reward?
   (*b*) If so, what is the explanation of the differences?
   (*c*) If not, what is the explanation of the apparent differences?

I cannot answer questions 1 and 2 with surety, and cannot answer question 3 with even an approximation to satisfactoriness. But I report the best answers I can give for whatever worth they may have.

The phenomena are not general. The formation of B⟶X by B⟶B⟶B⟶A + B⟶X, if A⟶X exists, does not always take place regardless of belonging and

after-effects. It may well be that, for certain sorts of X's in certain statuses of the total organism, the mere precedence and overlapping of A by B will cause the shift universally. But there does seem to be restriction in the X's and in the statuses. The C-R phenomenon seems much less general than ordinary learning.*

The phenomena of the conditional reflex are probably not the archetype of learning in general, the general basis or *anlage* out of which learning in general develops. They seem to be, on the contrary, a rather special case. Temporary modifiability by after-effects without permanent habit-formation seems to be a much more general and fundamental form. The *anlage* for learning in general seems to be in the early and widespread ability to continue or repeat a connection which is followed by certain states of affairs and to abandon or replace by some other a connection which is followed by certain states of affairs, in both cases temporarily, with little or no permanent modification of the organism.

One thing is certain. If learning in general evolved from the C-R phenomena, it soon took an independent course and became in general very unlike its parent, and developed a new type of associative shifting as a child of its own.

As to the third question, I am at present inclined to believe that there is a real conflict between the C-R phenomena and ordinary learning in the sense that neither will explain the other, and in the further sense that modifiability by a shift of certain X's from connection with A to connection with the precursor and overlapper of A occurs, and operates in ways radically different from those in which ordinary learning operates.

Light would be shed upon the third question, I think, if some investigator would observe animals of the same species forming the same connections, some by the C-R procedure and some by belonging, repetition, and reward.

* Some of the facts reported as instances of C-R modifications (including the often quoted facts of Krasnogorski ['26] in the case of children) are almost certainly simple cases of ordinary associative shifting.

We hoped to do this, using adult man, but have been so far thwarted by extreme difficulty in obtaining connections through the C-R procedure. Dr. Lorge reports the results of this work in Appendix X.

CHAPTER XVII

Minor Experiments, Comments, and Suggestions for Further Investigation

This chapter is a miscellany. It includes certain experiments and observations not particularly relevant to one more than another of our main topics. It includes notes on matters possibly fundamental in learning which have been left unmentioned in other chapters or in Appendices, because we had no new facts to report. It repeats with additional comments certain statements which have been made somewhat casually and briefly and incompletely elsewhere. Finally, it makes suggestions for further investigations of the dynamics of learning.

§ 1. Gradual strengthening *versus* the "all or none" principle

Because of the fact that single neurones act by an "all or none" principle, it has been surmised that the most elementary mental connections may either act in full or not at all, and further that the strengthening of such a connection may be typically or universally sudden. This would be in contrast to the orthodox view that a connection may gain strength gradually, creeping up, say, from 0 to 100 step by step.

We have taken ten of the simplest and most unitary responses we could think of, such as opening the mouth, stretching forth the right hand, and shaking the head, and had intelligent adults learn to connect each of these with one of a set of very easily differentiated visual presentations such as those of Figure 15. The subjects were first familiarized with the ten responses until they knew them all well. Then they were required to respond within five sec-

onds to each of a random series of the visual presentations, *Right* or *Wrong* being announced after each response, one response being, of course, *Right* for some one of the presentations and wrong for all the others.

The learning is rapid, but it does move step by step, with an increasing percentage of success, not by a sudden shift

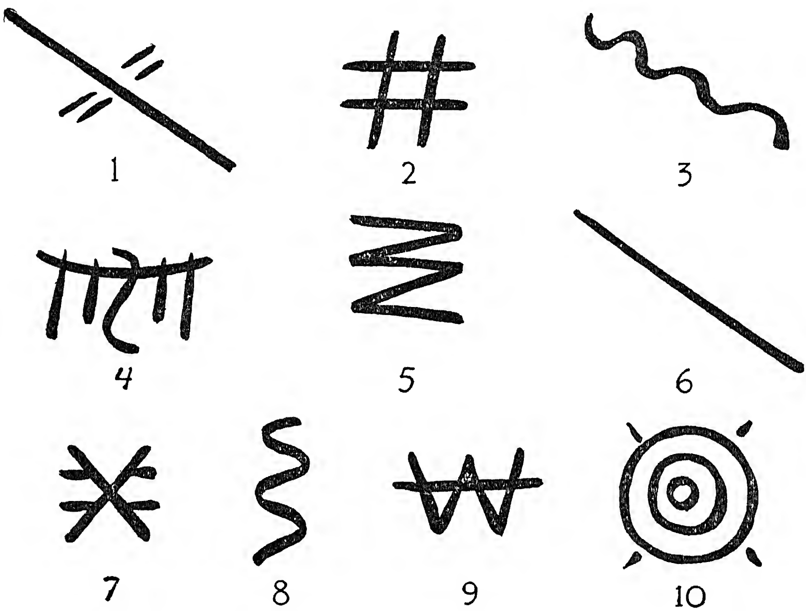


FIGURE 15. Ten visual presentations associated with ten simple and unitary responses.

from 0 to 100. The experiment can be made to show this more clearly, if the number of responses is raised to 20 or 30 or 200.

It may be hard to conceive of the physiological basis of a change from a probability of .005 for a mental connection to .01, then to .015, then to .02 and so on to an eventual .995 or 1.00. But some basis there must be, for such shifts are found. Let the situations be as distinguishable and the responses be as simple as we can make them, they still are found.

§ 2. Failures of satisfiers to strengthen connections

We had intended to include a separate chapter discussing the cases where we applied a satisfier to a certain connection and found it impotent to strengthen it. This occurred only in the case of hidden connections like those described in Chapter X. Even so, it occurred so rarely that we present here the cases of it which have not already been described in Chapter X.

In Experiment 84, sixty cards with flaps covering statements on the front and with statements on the back were studied, ostensibly for a memory test. The statements under the flap were interesting or valuable when the flap was held by black pasters and dull or valueless when it was held by white pasters. The reverse was the case of the statements on the backs of the cards. The subject lifted the flap, read the statement under the flap, turned the card, and read the statement on the back of the card for each card of the series. He went through the series three times and then was required to go through the series either lifting the flap or turning the card.

To prevent too easy awareness of the system, twenty-four of the sixty cards had flaps held by blue fasteners, and in these twenty-four, half of the cards had interesting statements under the flap and dull ones on the back, the reverse being the case in the other half.

In the lift or turn test, the cards with black fasteners were "lifted" 160 times and "turned" 164 times, and the cards with white fasteners were "lifted" 173 times and "turned" 151. The acts exposing an interesting or valuable statement were thus 311, and those exposing a dull or valueless statement were 337. There was thus no strengthening of the connection between black and "lift" or white and "turn" by the presumably greater satisfyingness of finding an interesting or valuable statement as a consequence.

Experiment 88

In Experiment 88 we used a series of cards with four-inch lines, like the series used in Experiments 58, 59, 60, etc., but with 1 right for red lines, 2 right for blue lines and black lines, 3 right for lines placed high up on the card, and 4 right for black lines cut across by white strips. A test series of ten judgments was followed by a training series of forty judgments and that by a second test series of ten judgments. In the training series, each judgment was followed by an announcement of *Right* or *Wrong* by the experimenter. We have then for each individual with each sort of card a record of twelve scores like that shown here for Du with red-line cards.

Test, 2 3; training 1 2 3 3 1 1 2 2; Test, 3 1.

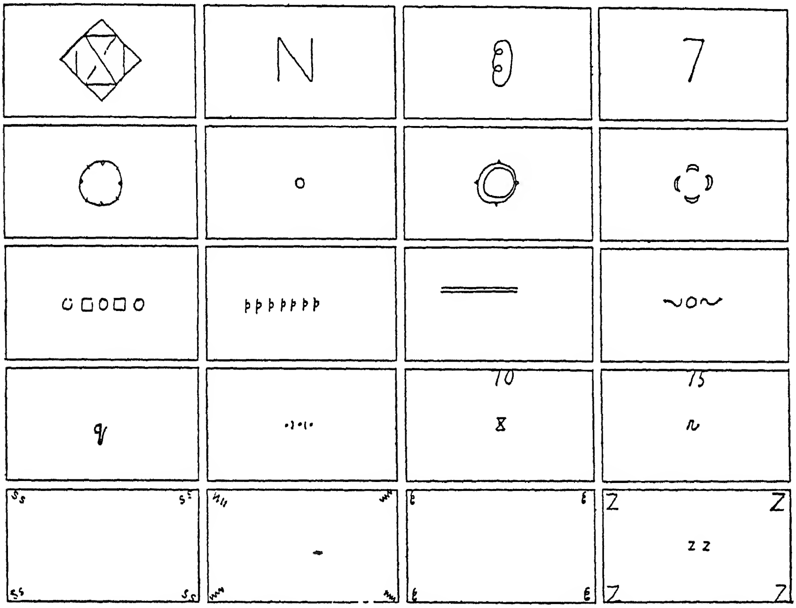
If any such record ends with a sequence of three correct responses, it is discarded as possibly involving an awareness that that color or position or cutting of the lines is often or always a sign that the number is the correct response. After such omissions the total number of right judgments for ten individuals in the initial and final tests is the same (26 and 26), and there is no gain during the training itself.

In a similar experiment with eleven other individuals, the totals for the initial and final test scores were respectively 28 and 34. In the records of this set the two varieties of cards which had 2 as the correct response were not kept separate. Because of this it is not possible to guarantee that two of the records used had no sequence of three blues correct or three black cards correct. But it is very unlikely. If the doubtful records are omitted, we have 27 and 31 as the totals.

It is probable that in this short training the subjects con tinued to the end to make an attentive comparison of the lengths on each card, and so never made any connections between the total appearance of any card and the response of 1 or 2 or 3 or 4.

Experiment 89

Experiment 89 is another attempt to measure learning in a case where the subjects of the experiments do not know what the learning is. It differs from the experiments hitherto described in that the sorts of responses which were rewarded were rewarded in a large percentage of their occur-



SAMPLE CARDS.

rences, but not always. Occasionally they were followed by the punishment of *Wrong.*

Cards were made with various figures drawn upon them (samples are shown above). As the samples show, large figures with thin lines were usually 1's, unless they were circular. Circular forms were usually 2's. Long narrow forms were usually 3's. Figures with heavy black lines were usually 4's. Cards numbered at the middle of the top were usually 5's.* Cards with something in or near each corner were usually 6's.

* These marks were much fainter than they appear in the reproductions.

There were four series known as Test *a* 1–9, 70-75, Test *b* 10-69, Training A 10-69 and Training B 10-69. Training A 10-69 duplicated Test *b* 10-69 with a few exceptions, but in a changed order. The subject always responded to a card by saying 1 or 2 or 3 or 4 or 5 or 6. He first (A) responded to Test Series *a* and *b* in conformity with these instructions:

"I shall show you a series of cards. Look at the card. Say the first number from 1 to 6 that comes into your head." No statement of right or wrong was made.

Next (B) he was shown Training Series A. To the above instructions was added, "I will tell you whether it is right or wrong"; and this was done.

Next (C) he was told, "Now let us see how quickly you can improve your score. Look at the card. Say the number that you think is right. If you have no idea, say the first number that comes into your head." Each response was followed by *Right* or *Wrong* from the experimenter.

Next (D) he was told, "We will try again. This time I shall not always tell you whether you were right or wrong." Training Series B was used plus Test Series *a*, no statements of right or wrong being made in the case of the latter. At the conclusion of C and also of D, the subject was told how many of the fifty cards had been answered correctly.

Next (Y) he was told, "This time say the first number that comes into your head," and shown cards 10 to 29 of Training Series A plus the cards of Test Series *a*. No statements of *Right* or *Wrong* were made.

Next (Z) he was told, "Say the number that you think is right. If you have no idea, say the first number that comes into your head," and was shown cards 30 to 69 of Training Series A plus the cards of Test Series *a*.

The subject was then asked to describe fully any ideas that he had about which cards were 1, 2, 3, 4, 5, and 6, respectively. Of ten subjects seven had absolutely no correct ideas at all. We examine their records first. The results are as follows: The number correct for Test Series *a* 1-9,

70-75 was 6 in A, 2 in D, 8 in Y, and 9 in Z. There was thus little improvement.

In the judgments of the particular cards which had been followed by *Right* or *Wrong*, there was an improvement of 58% from A to Y or Z,* but there was no increased tendency to respond to largeness by 1, circularity by 2, long narrow figures by 3, heavy black line by 4, etc.

Of the other three subjects, one had no correct idea at all about cards to which the correct responses were 1, 2, 4, 5, or 6; another no correct idea about cards correctly responded to with 1, 3, 5, 6; and the third no correct ideas about cards correctly responded to with 1, 3, 4, 5, or 6. For these three subjects, no correct ideas were reported for cards which were correctly responded to with 1, 5, or 6. For these three sets of cards the scores were 3 in A, 3 in D, 2 in Y, and 2 in Z. There was thus no improvement.

This result has been verified by experiments made by Mr. Tuckman upon seventeen college graduates and twelve thirteen-year-old boys. The totals for A, D, Y, and Z were 35, 33, 31, and 40, respectively, for the seventeen adults, and 26, 27, 18, and 24 for the thirteen-year-old boys.

The failure of the rewards to improve the scores was apparently due to the efforts of the subjects to find some system. If they had just naïvely taken a look and guessed each time so that the response would have belonged to the general appearance of the card, the tendencies to guess 1, 2, 3, etc., would probably have been connected with certain characteristic appearances or features of the cards. As it was, their ratiocinations did as much harm as the rewards did good, and their final scores were no better than the first guesses.

* Cards 10-29 of Test Series *b* were administered five times, in A, B, C, D, and Y. Cards 30-69 of Test Series *b* also were administered five times, in A, B, C, D, and Z. For the seven subjects who had no correct ideas at all the number of responses correctly made to the group of cards at each trial series is given below:

	A	*B*	*C*	*D*	*Y*	*Z*
For cards 10-29	35	42	51	48	49	
For cards 30-69	74	74	88	101		123

In one series of estimates of the lengths of certain strips certain subjects did not improve by training with *Right* and *Wrong*. But they did not improve by being repeatedly informed of the correct lengths. They were apparently so near their limit in this ability that improvement was impossible or too slow to be observed within the time of the training.

As these experiments suggest, there are two important limitations to the efficacy of a reward following a connection. The first is the degree of belongingness of the response to the situation. If situation A + B + C + D is followed by response 2 and a reward, there may be no strengthening of the $D \longrightarrow 2$ connection. The 2 may belong so exclusively to A + B + C that only $A + B + C \longrightarrow 2$ is strengthened.

The second is the interference of uncontrollable accessory conditions. Situation E may seem to be responded to now by 3, now by 4, now by 5, and now by 6 and $E \longrightarrow 3$ may be rewarded, and we may still find that $E \longrightarrow 3$ gains little or not at all over $E \longrightarrow 4$, $E \longrightarrow 5$, and $E \longrightarrow 6$. What happens in such a case is that the main situation E has along with it minor uncontrolled factors (as of accidental events in the neurones or their blood supply) or meets minor varying conditions (as in the muscles) so that really we have $E + w \longrightarrow 3$, $E + y \longrightarrow 4$, $E + x \longrightarrow 5$, etc., or we have $E \longrightarrow K$ which under certain conditions becomes 3, whereas under others it becomes 4 or 5 or 6. In the latter case we are rewarding $E \longrightarrow K$ not $E \longrightarrow 3$, and $E \longrightarrow K$ will continue, in the future as in the past, to appear now as $E \longrightarrow 3$, now as $E \longrightarrow 4$, or $E \longrightarrow 5$, or $E \longrightarrow 6$. A function at its so-called physiological limit is the best-known case. A person after training reaches a status where he can draw a line with an average error of 1/16 inch. Though you reward him every time that he is under 1/16 inch and do so thousands of times, you do not reduce his average error at all. The connection seems to be modifiable but really is not. Its results are modified by accessory conditions.

Apart from these two cases of apparent failure of re-

ward to strengthen, there may be for certain individuals in certain sorts of learning genuine cases of failure of satisfyingness to strengthen a modifiable connection. The test of such a one would be presumably that repetition of it did strengthen it whereas reward did not. We have encountered no such case in our experiments, and I am not acquainted with any demonstrated in the literature.

§ 3. Miscellaneous comments and suggestions

Attention. We have nothing of importance to add to what is known concerning attention in relation to learning. Attention to any given fact is a response or part of a response to it or a feature of the mind's set. Habits of attending are learned by exercise and effect as other habits are. The fruits of attention are well known.

Imitation and suggestion. We have no new data on these topics.

Disuse. We have made some observations of the influence of the lapse of time without use upon the strength of connections, but they are not important enough to be reported.

Negative adaptation. When a stimulus which at first evokes a certain response comes instead to evoke indifference, and this change is permanent, we have an important variety of learning. When the change is only temporary, we have a phenomenon like learning in some respects and like fatigue or inhibition in others. The change to indifference is doubtless in some cases, and possibly in all, due to its after-effects, but there may be inherent tendencies in the brain to do nothing rather than something to an oft-repeated stimulus, other things being equal. Such a gravitation toward neutrality and equanimity may play an important rôle in learning to neglect or to endure, and so in adapting man to his environment, over and above the adaptations favored by satisfyingness and annoyingness. This possibility should be thoroughly studied. We report some interesting cases in the chapter on the conditional reflex.

But we have not found time to make crucial experiments to differentiate learning not to do X by virtue of X's consequences, from learning not to do X by virtue of a sheer gravitation toward inaction.

The constitution of so-called "higher" forms of learning. It would be an interesting task to determine whether the so-called "higher mental processes" or "higher forms of learning," such as abstraction, the formation of concepts, the development of judgments and their use in reasoning, planning, and the solution of problems by foresight, require any other forces than those which we have found operating in simpler and "lower" forms of learning. A general consideration of the facts in the case [Thorndike, '14] led me to conclude that no others were needed. And experimental studies of the so-called "higher" processes in a typical case confirmed this [Thorndike, '17]. Our study of "transcendental" systems in Chapter XIV is a further confirmation. But I may have been misled by antipathy toward mysterious faculties or powers, or by ignorance. The final determination of the problem must include an explanation of a sufficiently large random sampling of "higher" processes. We might take, for example, learning of the theory of exponents, solution of originals in geometry, learning the grammar of a language and using it to work out the meaning of sentences, learning physical principles and solving problems by them, and learning and using the laws of Mendelian inheritance. Suppose that all those, when observed impartially and adequately, were found reducible to the readiness, formation, and action of connections between situations or elements of situations and responses or features of responses, including connections which release, restrain, accentuate, weaken, cherish, discard, put in readiness or make refractory other connections, and to changes in the identifiability of situations and availability of responses. We might then be reasonably sure that no special "higher" faculties or powers would be required anywhere.

Strengthening one connection by restricting others. It is sometimes useful to consider the action of the connection $A \longrightarrow B$ as equal to $A \longrightarrow$ *avoid all save B*. We then think of the attainment of B as the restriction of connections to aught else. In the brain, the same end-result might be attained by the inhibition of all tendencies save one, as truly as by the dominance of that one. Such an extreme condition as this may never occur, but conditions of mixed emphasis of some and restraint of others are probably very common. An early and important action of A plus the set in which it occurs may be to rule out certain tendencies.

The variability of connections. It is also sometimes useful to consider the action of the connection $A \longrightarrow B$ as $A \longrightarrow K$ *plus an "error"* or variability which the connection cannot control. We may attribute the error to a failure to rule out some of the responses most like K, or as due to disturbances of one sort or another acting on the $A \longrightarrow K$ connection. The former seems the more likely. This $A \longrightarrow K \pm$ *error* nomenclature is specially useful in cases where the operation of the connection results in a variable response, $A \longrightarrow B$ being differentiated from $A \longrightarrow C$ or $A \longrightarrow D$ or $A \longrightarrow E$ by the fact that the B variable is on the average closer to some desired ideal or standard response than the C variable or the D variable or the E variable is. So, in acts of skill, the A response may be to put a bullet, on the average, 2 cm. from the center instead of 2½ cm.

The form $A \longrightarrow K \pm$ *a certain amount of variation* is more fundamental than the rigid $A \longrightarrow$ *a fixed and uniform K*. All or nearly all original unlearned connections are of the type $A \longrightarrow K \pm V$, and the $A \longrightarrow K$ type develops rather rarely until there is a fund of rigid responses made available by training. These latter reach an enormous number, as in language and mathematics, but their prevalence in sophisticated human learning should not blind us to their essentially secondary nature. Fundamentally a connection operates as an approximation and is a variable fact.

Like results from unlike connections. In some circum-

stances the same final result for behavior may be attained by the strengthening of very different connections. Thus suppose that situation S_{295} in person P 314 when responded to by response R_{923} produces a satisfying state of affairs Sa_{678}, whereas R_{924} produces state of affairs An_{1021}. Suppose that after a certain number of trials the person in question changes from 50% of R_{923} and 50% of R_{924} to 100% of R_{923} and 0% of R_{924}. He may have strengthened $S_{295} \longrightarrow R_{923}$ without knowledge that R_{923} for S_{295} produces Sa_{678}. He may have strengthened $S_{295} \longrightarrow R_{923}$, and also the informational connection that R_{923} produces Sa_{678}. He may have strengthened only the latter, inferring each time what to do to S_{295} from his growing confidence that R_{923} will produce Sa_{678}. The mere fact that learning occurs does not tell us in such cases just what has been learned. Many of the disputes about the theory of learning arise from this: and our elaborate experiments in Chapter X were devised to avoid such ambiguity.

In the practice of learning, the knowledge that such and such will do so and so is often obtained when what is really needed is the proclivity to do such and such. Sometimes also a blind proclivity to do such and such is accepted when by only a little more care the rationale of the proclivity could be learned as well, and the proclivity thus be established more firmly.

The ubiquity of after-effects. It has been too customary to think of the action of the after-effects of connections as influential only in the cases of emergencies and crises and main features in learning; and only in the form of emphatic rewards and punishments. Our hypothesis would be that the after-effect of every modifiable connection influences it. The amount of influence may be zero in the case of after-effects near neutrality, and may not be beneficial for learning in the case of annoyers whose influence is to cause panic, balkiness, or other harmful or useless responses to the situation. But the Law of Effect is a general law, zero action being a special limiting case. It is not a spe-

cial phenomenon true only for obvious rewards and punishments.

It used to be customary to describe purposive action and thinking as mere habit and association plus control or direction. This is in a sense true, but it is misleading in its suggestion that an aimless unmotivated flow of acts and ideas is more primary and more natural, and that we get purposive action and thought by adding something selective and directive to it. On the contrary, primitive action and thought is usually instigated and accompanied and directed by some want. The wavings of arms and legs by an infant are, if anything, more motivated than its father's walk to his office. The stream of ideas of a two-year-old playing with her doll may be more motivated than the ideas she has ten years later during an average hour in school.

If you give a person paper and pencil and say, "Do one thing, then another, then another with these, until you do the right thing. I will tell you when you do the right thing," the person does not as a rule indulge in a series of movements each, after the first, a habitual sequent of what has gone before. More often he indulges in a series of tasks such as writing words, or making pictures of objects, setting himself, as it were, a series of orders or problems.

The influence of after-effects in general. We have suggested that better knowledge of when and how a satisfying state of affairs strengthens the connection which accompanies it or precedes it by a second or so and to which it belongs, may be attained by an investigation of the action of satisfiers in general. It seems in cases of learning to have this strengthening influence always. We should check this by experimenting with a score or a hundred randomly chosen cases (like an enjoyable sweet taste, a comfortable posture after hard muscular work, deserved praise from an honored leader, catching what one is eagerly pursuing, and the like) and determining just what connection was operative in the second or two preceding and just what change, if any, it underwent. The satisfier seems to act

directly upon some trace or relic of the preceding and belonging connection. We should check this by the experiments just suggested, by experiments like those of Chapter XII, but more ingenious, extensive and varied, and by other experiments, if necessary. With certain modifications, this paragraph applies to annoying states of affairs also.

We have stated that both satisfiers and annoyers have their power in learning by what they make the animal do or keep him from doing. The annoyers do not, by our view, necessarily act to weaken what precedes and belongs to them directly, or indirectly by strengthening all other relevant connections than it. They act often, conceivably always, by evoking some other tendency or tendencies, one of which may be much strengthened if it brings the satisfyingness of relief from the annoyer. In the case of satisfiers, the action upon the status of the moment including traces of the connection active a second or so ago seems the important thing for learning, since the action in the forward direction is usually (in the case of learning) to maintain a status of rest or undisturbed progress to the next stage of the procedure. But all this should be the starting-point for further experiments. What do satisfiers cause animals to do then and there? We have noted the very frequent causation of a continuation or repetition of the preceding belonging connection. How uniformly does this occur? Under what conditions does it not occur? What else besides such continuation or repetition does a satisfier favor? These are all questions the answers to which should be profitable.

In order to keep free from variations in intensity and relevance, we have used symbolic satisfiers and annoyers (*Right* and *Wrong*) in our experiments. Having determined their influence in the respects which were essential for the problems we were attacking, a next step should be to compare various intensities of satisfyingness and annoyingness, various degrees of relevance (for example, a shock in the hand that underlines a wrong word *versus* an equally

annoying shock in the foot), and various degrees of "belonging" and fitness to the mental "set" (for example, attaining the food you are trying to get *versus* having it vanish and a different but equally palatable food come to you mysteriously like manna from heaven*).

Further investigations should be made to determine the extent of influence of a satisfier. Our experiments demonstrate its influence upon the connection which very closely precedes it and to which it belongs. Facts presented in Chapter XVIII suggest that it may not influence at all connections which have ceased operating and been replaced by others. So far as I know, there is not a fact in learning which requires that the action of the satisfier should pass by the connection immediately preceding it and strengthen an earlier one not more attended to and not more closely belonging. It apparently works very simply, strengthening whatever traces are there in some proportion to their belongingness. But all this should be tested by experiment. "Belonging" is characteristic of what is strengthened in our experiments, but there is some evidence that an immediately preceding response to which the satisfier belongs only very slightly if at all, may be strengthened by it. When a cat is rewarded by the opening of a door giving freedom or food as soon as it licks itself, the reward in the first few trials can hardly belong to the connection, *confinement in that box*$\longrightarrow$*licking oneself*. Yet that connection is slowly strengthened. Scratching oneself and stepping on a platform in the back of the cage are other illustrations. We need experiments in which responses made inadvertently are rewarded to see how far proximity in time is adequate without belonging. In particular we need to know the influence of differences in belongingness for times of 0 sec., ½ sec., 1 sec., 1½ sec., and 2 sec.

The effects which have practically monopolized what little

* This is a very poor illustration, since the former would probably have a much greater intensity of satisfyingness under the circumstances, but I cannot now think of a means of securing states of affairs equally satisfying but varying in fitness to the mental set. To devise such would be part of the task.

discussion of after-effects there has been, are satisfyingness and annoyingness, or states of affairs considered according to the amount of satisfyingness or annoyingness which they possess. It would probably be profitable to study also excitement and calm, muscular tension and muscular relaxation, restlessness and quiescence, and other effects of the action of connections.

Connections in general. As noted elsewhere, the principles found by these investigations to hold good for connections of knowledge and skill should be tested in the case of connections involving emotions, attitudes, desires, purposes, and the like.

The organization of connections. We have from time to time emphasized the extreme complexity of the organization of mental connections, especially in the case of man. Their number is legion. Their action varies with the mental set in which they act. Their first terms may operate piecemeal, forming preferential bonds. They may coöperate in an almost infinite number of combinations. They may possess different degrees of potency or weight in determining the total response. They include connections releasing, restraining, depressing, and accentuating other connections. They include tendencies to attend and to neglect, to welcome and avoid, to put some processes in readiness and others in a refractory state.*

* Many of the arguments and criticisms directed against connectionism are valid only against a narrow and oversimplified connectionism which would assert that mental life was nothing but a series of small isolated elements arranged in one row in time, and that each of them formed connections by itself alone and only with the one coming next after it.

If the laws of belonging, exercise, and effect operated in such a system, it would be impossible for me to write *Thornhill* or *Thornberg* or *Thorniness* since I have written *Thorndike* with satisfying consequences thousands of times and have written *hill* or *berg* or *iness* after *Thorn* seldom or never. Indeed, since I have probably written *The* more often than *Tho,* I probably cannot write my own name but must follow the beaten path of *Th* to *e* if I am fortunate enough to get as far as *Th.* If, in early steps in writing, I had been led to write *To* ten times at first, I could then never have written aught else than *To* till I died.

Many of the criticisms of connectionist psychology made by advocates of

The organization of connections thus offers a most fruitful field for investigation. For example, the psychological problems of education will be attacked with much better prospects of success when each change to be produced is stated in terms of the actual connections or features of connections and readinesses which constitute it.

The influence of changes in one connection upon other connections. Changing the strength of any one connection (say, increasing the probability that S_{2968} in Set_{435} will evoke R_{6435} from .00001 to .99800) may and often does appreciably alter the strength of certain other connections. Experiments to prove this directly cannot be quoted, but the extensive literature on the influence of improvement in one mental function (the term function is used to mean certain groups of connections and readinesses acting in certain sets to produce certain results) upon the efficiency of other functions indicates that functions interact not only by the possession of connections in common, but also by the possession of parts of connections in common. After we have allowed, or think we have allowed, fully (by a control experiment) for the total connections common to the two functions, there is likely to be an unexplained balance or "transfer." As Bray says in reporting a recent study of this sort, "The instructed groups do not show as great accuracy as the transfer groups, and it is not known to what this difference is due" ['28, p. 466]. These unexplained balances in Bray's own work, for example, may be in part accounted for by the parts of the connections which concern movements of the eyes or head, as he suggests.

various forms of purposive psychology or by advocates of Gestalt psychology consist in dignified elaborations of the thesis that they can write many names and the like, and that consequently connectionist psychology is unsound. Obviously I can write *Thornjjj, Thornxzfp,* or *Thornquvp.* But that does not prove that purposes are not made out of connections and readinesses or that the action of the brain is organized by Gestalten over and above the connections born and bred in the neurones, or that learning is not connecting.

CHAPTER XVIII

Adverse Evidence and Arguments

The contents of this chapter will include a presentation and discussion of (1) alleged evidence in favor of the potency of the repetition of a situation to strengthen the more frequent connections at the expense of the less frequent, (2) alleged evidence against the potency of the repetition of a connection to strengthen it, and (3) alleged evidence against the potency of satisfying after-effects of a connection to strengthen it.

It will include also (4) the more general criticisms of the Law of Effect and (5) the doctrines which have been put forward as substitutes for it, including (6) doctrines which admit an indirect potency of after-effects *via* representations but deny them direct influence upon the connections at the time of their occurrence.

§ 1. Alleged evidence of the potency of the repetition of a situation

The first of these six, the alleged evidence that, as a situation is repeated, the more frequent connections leading from it increase their strength at the expense of the less frequent, need not detain us long. There is no such evidence. Watson and others, who have used frequency as a principle of selection in learning, have all simply begged the question. As was demonstrated in Chapter II, the mere repetition of a situation will not produce the strengthening of the tendency to respond to it by A rather than B, C, D, or E, even if A is ten times as frequent as B or C or D or E. A rat in a maze that chooses path A four times and path B once in the first five trials will, so far as the mere confrontation by that situation goes, choose path A no more than

four times in the second five, or the third, or the fourth, or the fortieth. It is only when some force is applied to disturb these relative frequencies that they are altered.

§ 2. Alleged evidence against the power of the repetition of a connection to strengthen it

Various writers have noted that mere repetition of a connection is weak and that rapid and effective learning requires attention, or interest, or the will to connect the two terms, or the active responding with the second term to the first as its situation as in "reciting" rather than reading, or the organization of the two into some sort of unity. A few, chiefly enthusiasts of the Gestalt group, have denied it any potency. Koffka, for example, says: "Repetitions without the achievement of a structure remain ineffective, if not harmful. Practice is the formation of a structure, . . . not the strengthening of a connection" ['21, p. 167].

Ogden says: "Unless a pattern is formed which suggests its own completion, the first syllable of a pair will not recall the second even after the two have been repeated together hundreds of times. What is remembered is always a configuration, the members of which hold together precisely for the reason that they are members of a configuration ['26, p. 210].

The evidence which would be adduced to support this denial is chiefly certain results obtained by Lewin, Sigmar, and Van der Veldt.

The valuable experimental results of Lewin ['17 and '22] have been misrepresented as strong evidence that a situation (S) which has been often followed by a response (R) does not thereby acquire a tendency to evoke it in the future. This misrepresentation is probably in part due to Lewin's use of the phrase "fundamental law of association," in connection with his specific criticisms of Ach's doctrine of the associative equivalent and Ach's use of the real or alleged strength of certain connections as a means

of measuring the strength of some tendency (of will or purpose or frame of mind) which just barely counterbalances or overcomes or inhibits them. Lewin himself was at first careful to specify that, "The question which is submitted to test in the following main experiments concerns itself with the validity of a quite definite law, and is not formulated with the purpose of determining whether a certain psychological trend (*Richtung*), that of Association-psychology, is right" ['22, p. 196].

What Lewin's results show is that the mental set, the status of the person's mind, coöperates with and is often prepotent over the connections which have been made between certain elements or features of mental life and other elements or features which have often followed them. In particular, they show that in the case of sequences of nonsense syllables the kind of activity (such as finding a rhyme for the syllable, or reversing the initial and final consonants of the syllable, or replacing the vowel of the syllable by *i*, or learning to pair another given syllable with it) which a person sets up plays a very large part in what presentation of a syllable will evoke, whereas the past sequents of the syllable play a very small part (unless the activity that is set up is to give a past sequent of the syllable, when, of course, they will play a large part).

I present briefly two typical experiments of Lewin, one exemplifying the cases where a rather strong connection fails to interfere with or inhibit some alternative activity and one exemplifying cases where a rather weak connection coöperating with a certain activity does so interfere.

I.—Lists of nonsense syllables were read or recited from memory 270 times in all. One of these syllables, say *tel*, then has a strong tendency to connect with its sequent, say *pom*, when the mind is set to say the list in question, and presumably has a fairly strong tendency to connect with *pom* when the mind thinks *tel, what came next in the series I was learning?* These are the syllables with uniform sequents.

Six other lists including 70 different nonsense syllables, were read from one to six times each, the order of the syllables being changed each time in cases where the list was read more than once. These are the neutral syllables, without uniform sequents, to be used as later described. They were read so that when seen later they would not be easily distinguishable by their unfamiliarity from the syllables with uniform sequents.

One series of 12 still different syllables was used to give the subjects practice in the task of reversing the first and last letters of the syllables, in accordance with these instructions: "Read the syllables that appear, softly, and then state the reversed syllable. But do not simply read the syllable backwards" ['22, p. 204]. These 12 reversal syllables were thus reversed daily for three days.

Then three lists of syllables were made, each beginning with two syllables which had had no uniform sequents (neutral syllables), and thereafter alternating those which had had a uniform sequent 270 times with those which had had no uniform sequents. The subjects were required to read and reverse as above, after first repeating once more the reversing of the 12 reversal syllables. The question was whether the syllables which had had uniform sequents would tend to evoke these sequents and thus hinder the subjects in the task of reversing the initial and final letters, delaying them or even causing them to give the previous sequent instead of reversing the syllables. There was little or no such hindrance, the average time for the syllables with uniform sequents being .632 sec. or only .030 sec. longer than the median time for the neutral syllables (.602 sec.).

II.—Eight syllables were used. In the case of four (a, b, c, and d) the subject always had to say a certain syllable to rhyme with the given syllable. He must replace initial *t* by *d*, *k* by *g*, and *p* by *b*. In the other four (e, f, g, and h) the subject always had to reverse the initial and final letters.

The practice connected each syllable with its sequent only eight times. Then the subject was given syllables a b c d with the instructions to say the rhyming syllable for each. Then he was given (with the same instructions) syllables a b e c d, and then syllables a b f c d. Syllables e and f thus inserted are likely to evoke the wrong response of reversing or cause a notable delay in the process of changing its first letter from *t* or *k* or *p* to *d, g,* or *b*, respectively, although they had been followed by their reversals only eight times each.

In this sort of experiment, the subject is led or tempted to do to each syllable what he has done before rather than simply to do what he is instructed to do at the time. We may then explain the presence of interference here by the same principles as its absence in the former case, namely, that his behavior is determined chiefly by what he is trying to do to the syllables rather than by what past sequents they have had, and how often they have had them.

Lewin's later theoretical statements ['26, p. 311 and elsewhere] do not follow at all necessarily from his experimental findings.

All of Lewin's discussions and the interpretations of them made by others should be read in the light of the particular connections and activities with which he experimented. His experiments do not prove that the activity set up is always enormously potent over the past sequents of the elements with which it acts. For example, if the reader sets for himself the activity of saying backward the alphabet or Lord's prayer he *will* be notably delayed by connections formed in the past and he can overcome the delay precisely by putting the power of frequency and satisfying consequences on the side of z⟶y⟶x⟶w⟶v⟶u, etc. If the reader sets for himself the task of mirror drawing, the connections formed in the past *will* be at the start prepotent over the desired activity of *moving in the way I ordinarily would not.* It is precisely by building up a new set of connections attached to the mirror-drawing

set of mind by frequency and resulting satisfaction that he will become able to shift back and forth from tracing a directly seen star to tracing a star seen mirrorwise, without interference. When he can do this he is in a position to determine his behavior by using the one activity rather than the other, but this is not because the connections due to past sequents and satisfactions are unimportant, but because he has both sets at his command.

The assignment of relative importance in general to (1) what mental stuff or fact or element is present, (2) what connection it has as a result of past experience, and (3) what activities the mind uses in dealing with it, is not a suitable subject for general settlement since it varies so greatly. But it is surely unreasonable to try to reduce the importance of the second to zero everywhere. If I say, *11, 4, add the second to the first,* and later *11, 4, subtract the second from the first,* it is doubtless important that the person should add or subtract as he is told, but it is also important that, having undertaken this activity, he should have connections leading from *add 4 to 11* $\longrightarrow$ *15* and from *subtract 4 from 11* $\longrightarrow$ *7.* Even in Lewin's experiments, where the set of the mind and the readiness of certain responses shunts off the tendency of a nonsense syllable to call up or tend to call up a past sequent almost as much as is possible, that tendency is still not reduced to zero.

Some of Lewin's later theoretical statements, in which he almost or quite denies the strengthening influence of repetition, do not follow necessarily from his experimental findings. The most extreme is, perhaps, the following: "The experimental investigation of habit (*Association*) has resulted in showing that the bonds produced by habit as such never serve as the moving force (*Motor*) of a mental event. Such a view is also in error even if one regards the essential of the processes of habit and practice not as the formation of isolated (*stückhafter*) associations, but as the transformation and origination of large organized units of behavior (*bestimmter Handlungsganzheiten*). The nec-

essary condition to determine whether in general the mental event shall run its course wherever that may be, is found rather in certain mental 'Energies' which as a rule go back to a pressure of will or craving" ['26, p. 311].*

Van der Veldt ['28, p. 32] found that a subject who had read twelve nonsense syllables always in the same order over three hundred times could not say them in order except after an elaborate indirect process of inferring what they were. He had been concerned with reading them one at a time, responding to each of them by a certain movement, and had formed the connections Syl 1→movement 1, Syl 2→movement 2, and so on. He used these and the connections movement 1→movement 2 to reconstruct the series Syl 1, Syl 2, Syl 3, etc. But the connections Syl 1→Syl 2→Syl 3 and so on had been strengthened little or not at all. The syllables were thus to him a series of separate imperative sentences, not belonging one to another. Van der Veldt himself, as observer, heard the series read aloud 2490 times, but could not recite them in order. In his case, not only was there no belonging, but the time intervals were filled with matters of interest (managing the experiments, making records, etc.).

These are very beautiful illustrations of the importance of belonging and interest, just as Lewin's experiments offer beautiful illustrations of mental set and readiness, but they do not disprove the potency of repetition of a connection.

Van der Veldt ['28] had subjects connect certain nonsense syllables with certain appearances of lights at twelve positions on a keyboard. In the simple motor series (SM)

*Even here it will be noted that Lewin does not absolutely deny the potency of repeated connections. They never "*abgeben den Motor*" of a mental event, but perhaps they can condition it. Moreover he is repudiating equally more elaborate organizations. Neither they nor single connections are the "*notwendige Voraussetzung*" of what happens in the mind. But perhaps they are contributory.

It is perhaps rather the desire to accentuate and dignify the needs, cravings, purposes, or drives which conditions behavior than any genuine and serious belief that the repetition of connections is futile which leads Lewin to make the statement quoted above.

the subject tried to touch the right lights in the right order without looking at them. In the simple sensory series (SS) the subject tried to notice (by indirect vision) the positions of the lights and remember them without using verbal or numerical equivalents for them. Various complexities and modifications were introduced in later experiments. He concludes that:

"1. The training (*apprentissage*) as such has no effects that are genuinely (*proprement*) dynamic; it does not automatically condition a tendency to execute the movement learned, when the subject finds himself placed in more or less similar situations (*conditions de milieu*).

"These effects appear only in cases where they are activated by actual tendencies of the subject, for instance, by the intention which he has of reproducing the old movement" ['28, pp. 336 f.].

The first paragraph is true if sufficient allowance for real effects of the training is made by the "as such," "genuinely," "automatically," and "more or less similar." The second paragraph is true if "actual tendencies" is interpreted broadly enough.

But it would be just as true an account of the results of the experiments to say that:

The training as such has a genuine dynamic effect; it causes a tendency to execute the movement learned if the situation permits.

This effect appears whenever it is not suppressed or shunted off by directions or conditions which conflict with it, even if the subject has no intention of operating the old connection.

The repetition of the connections between certain syllables and certain movements did have real effects. For example, subjects who had learned to move the hand to touch certain positions at the sight of certain syllables, and were then required to remember what the position was in each case, but to touch always one same spot, did occasionally make the movement formerly connected with that

syllable (in 1.2% of 1536 trials). If the subject is distracted so that he neglects the present instructions, he usually makes the old movement. Other evidence that the practiced connections had real strength appeared in the experiments in which the positions were numbered and the subject was told to make a series of touches in the order 1, 2, 3, 4, 5, etc., while reading to himself a series of nonsense words. Sometimes the order of the touches which had been connected in the past training with these series of nonsense words was the same as the order of numbers which the directions bade the subjects follow. In such cases the subjects did tend, in 14.7% of the cases, to look toward or move toward the position that had been connected with the first syllable, rather than to the position marked 1. There were 8% of continuations of the movement as by the old connections instead of the new instructions.

Further evidence of the same sort was found when the subject had to read old syllables but touch four lights as they successively appeared. There were tendencies to make the old movement at the start in 52% of the cases with naïve subjects. Continuations of the movement as by the old connection occurred in 44% of the cases.

Still more evidence to the same effect appears in the experiment with movements reduced in amplitude, and the experiments on inhibition. (See pages 308-323 of Van der Veldt's monograph.) Indeed, unless my reading has been careless, the repeated connections displayed potency in every test which Van der Veldt made. What he has shown in Part Three of his monograph is not that they are impotent, or less potent than a thoroughgoing connectionist should expect, but that they work under the conditions of the mind's set or purpose, not as utterly independent and isolated forces.

In general, fact after fact in his thorough investigation shows the potency of repetition. It is reduced nearly or quite to zero when belongingness is absent, and swamped or hidden when the interests and sets of the mind are not

favored by its operation, but it is there beyond question. It always acts when it has a chance. He is interested in showing the importance of the sort of facts which we have discussed under belonging, readiness, systems, mental sets, the coöperation of connections, inhibiting and facilitating connections, and restraining and releasing connections. He does so in part by minimizing the importance of the mere connecting of the most obvious and uncomplicated sort. That is his privilege, and I, for one, will endure any amount of minimizing of the Law of Use, or the Law of Effect, or connectionism in general, if it comes along with experimental work as solid and ingenious and faithful as that of Lewin or Van der Veldt. But it is not really necessary to decry the potency of repetition or the simpler facts of connection-forming in order to show the facts of readiness, interest, and mental set or adjustment.

§ 3. Alleged evidence against the power of satisfying after-effects to strengthen a connection

Denials, expressed or implied, of the potency of after-effects have been numerous, almost general. That doctrine has also had to suffer what is psychologically the most extreme form of denial, neglect. But the evidence adduced to support denial or skepticism is rather scant. We shall deal with all such evidence that is at all important.

The fact that, in maze-running, errors temporally near the food-box are not eliminated very much faster than errors elsewhere has been used as evidence that the satisfaction of arrival at the food-box does not specially strengthen the connection whose sequent it is. This fact, as well as the alleged fact that delay in presenting the reward does not greatly reduce learning, has been used as evidence against the Law of Effect in general.

The irrelevance of the first fact will appear in the course of a study of the second. So we will consider that first.

Watson ['17] had rats learn to dig their way into the place where the food was. Some of them were allowed to

take the food at once. The others were restrained therefrom for 30 seconds, at the end of which time a lid was removed enabling them to feed. "After an animal, working by the immediate feeding method, had scratched away the sawdust and entered *b*, the door was closed and the food-box immediately opened. . . . The rats were allowed to eat for five seconds and then they were lifted out and taken back to their living cages. Only one trial per day was given. Exactly the same method was adopted for the group working by the delayed feeding method except that in this case the *lid to the food-box was held down for thirty seconds*" ['17, p. 53].

There was no appreciable difference between the two groups in the curve of time required to reach the place where the food was. Both learned where to dig, and reduced their time to 6 or 7 seconds after about 20 trials. Nor should we expect otherwise. The rats had been allowed to get their food in the box before the first trials were given. They presumably dug in order to get into the box. When they got into it they took the food if the lid was off. If it was not, they "became frantic. They would fight the rod, tear at the box, then they would leave the neighborhood of the food-box immediately, pass back through *c* to the under-floor space, and then return to the food-box." [Watson, '17, p. 54.] If any of these activities had been constantly rewarded, it would presumably have been favored as trials progressed. The behavior of both groups is explainable if the satisfier that made them dig at a certain place was getting to the place where food had been had.

Warden and Haas ['27] also found little difference in the time and errors in running a maze when the food was withheld for a time. Their results also are explainable on the hypothesis that the satisfier effective in stimulating the rats to run and run directly was reaching the place where the food was, whether covered by a funnel or available for immediate appropriation. The later work of Miss Haas

(Mrs. Hamilton) ['29], in which the animal was restrained in a pathway unit during the delay period, justifies this explanation.

She measured the influence of delaying the feeding for 0, 1, 3, 5, and 7 minutes after the rats reached the end of a maze upon the progress of the animals in learning the maze. Using as a norm of achievement two correct runs out of three, all the 0 delay rats had reached the norm in 20 trials, whereas only about 55% of the others had. The average number of trials, errors, and seconds required by the different groups to reach this norm was as follows:

16 rats	0 min. delay	10.3 trials	34.8 errors	131 seconds
22 "	1 " "	20.3 "	64.3 "	278 "
22 "	3 " "	20.7 "	68.5 "	380 "
20 "	5 " "	22.2 "	77.1 "	429 "
25 "	7 " "	17.5 "	60.2 "	390 "

The rats were trained further until they reached a norm of four perfect trials out of five, except for nine rats who failed to reach it in 99 trials. The difference between no delay and delay is still more marked by this norm.

The 0 delay rats had all attained it in 30 trials, at which stage only 59.1%, 13.6%, 30%, and 44% of the 1, 3, 5, and 7 minute delay groups had done so.

The nine rats that failed in 99 trials with delay were then trained with 0 delay in feeding and then learned very rapidly. Their average times in trials 95, 96, 97, 98, and 99, were 22, 23, 27, 35, and 35, respectively. By trials 102, 103, 104, and 105 it had fallen to 11, 8, 9, and 8, respectively. The average number of errors dropped from 2 to 0.5. By the 105th trial, all nine animals had attained the norm of four right out of five.

Mrs. Hamilton demonstrated the influence of delayed feeding also by the obstruction method. The rats crossed the grid receiving its electric shock an average of 17.6 times when they were fed with 0 delay thereafter; but with delays of 15, 30, 60, and 180 seconds, the average number of crossings was, respectively, 10.0, 8.3, 9.3, and 4.7.

We may usefully consider Mrs. Hamilton's results in a way which she does not take, namely, by comparing the after-effects of the learning and its alternative, and of the crossing of the grid and its alternative.

In the maze-learning, an animal may run the maze without errors or he may run it with one or more errors. If he does so two times out of three he is said to have learned it to mastery A; if he does so four times out of five he is said to have learned it to mastery B. In both cases he is rewarded by food after 0, 1, 3, 5, or 7 minutes delay according to the group he represents. In both cases in the Hamilton experiments, he gets all he can eat in ten minutes, one minute in the maze and nine minutes thereafter in his regular eating place. In the former case, he usually gets the food somewhat quicker because errors and time usually correlate. The incentive or reward for mastery *versus* errors in maze-learning is, in general, not getting food, but getting it sooner.*

In the case of the 0 delay rats the effect of an errorless run *versus* a run with errors (say, an average run during the first five trials, which had an average of 5 errors) is to get started eating about 7 seconds after you are put in the maze at the entrance *versus* about 18 seconds after you are put in the maze at the entrance.

In the case of the delay of 1 minute the corresponding times are about 67 seconds and about 80 seconds (81 seconds if we use the average 6-error record of the actual first five trials of these rats).

In the case of the delay of 3 minutes, the corresponding times will be about 190 seconds and 205 seconds. In the case of the delay of 5 minutes, they will be about 310 seconds and 330 seconds.

We should then expect that these feedings after delays of a minute or more would be about equally ineffective, since food after 67 seconds can hardly possess any great su-

* Maze-learning could be arranged so that the animal would get food only when he traversed the maze without error, but this has rarely or never been done.

periority over food after 80 seconds either as a "motivated learning situation" *à la* Hamilton or as a satisfier *à la* Thorndike. They were about equally ineffective, and 3 minutes seems quite as bad as 7.

We should expect the learning with feeding after these delays to be very, very, slow, as it was (see Hamilton, '29, p. 186). In fact, if Mrs. Hamilton had not prevented a rat as soon as it got to the end of the maze from retracing by shutting a door, the learning with the delayed feedings would probably have been very much further behind that of the 0 delay rats than it was.

The essential fact of the experiments seems to be that the difference in satisfyingness between abundant food after n seconds and abundant food after $2n$ or $1\ 1/2n$ seconds is potent but that a similar difference between n and $16/15\ n$ or between n and $26/25n$ is not.

Consequently I make no claim that Hamilton's findings prove the correctness of my hypothesis that a satisfier must be fairly intimately connected with a tendency (by proximity in time and by belonging or otherwise) if it is to strengthen it. They rather prove that of two satisfiers about equally intimately connected with two tendencies the greater will have the greater strengthening influence.

In the experiments by the obstruction method, a rat was first taught that by crossing the obstruction chamber he could get food by four immediate feedings of "a nibble of food" after such crossings. Then he was given a shock the fifth time, but also was given the nibble of food. Then the actual test began. He was put in the entrance chamber and observed during 20 minutes, count being made of how often he crossed through the obstruction chamber where he now each time received an electric shock, how often he approached it but did not go in far enough to receive a shock, and how often he went in far enough to receive the shock and then drew back. When he crossed he was given a nibble of food after 0, 15, 30, 60, and 180 seconds and then put back in the entrance chamber. The 15 or 30 or 60

or 180 seconds of delay was not counted in the 20 minutes. There were 20 rats in each group.

The 0 rats averaged 17.6 crossings; the 15-sec. rats, 10.0; the 30-sec. rats, 8.3; the 60-sec. rats, 9.3; and the 180-sec. rats, 4.7. The total number of approaches, contacts, and crossings, which may be taken as a rough measure of the interest of the rats in getting the nibble of food, averaged 26.9, 34.6, 35.6, and 26.0. The delay in obtaining the food was thus clearly potent.

Here again we may profitably analyze the results from the point of view of the consequences of a crossing as compared with (1) staying in the entrance chamber and avoiding the obstruction chamber entirely, (2) approaching the latter, and (3) going in and retreating.

In the experiments by the obstruction method, the response of crossing the grill had as its consequence an electric shock plus a nibble of food after 0, 15, 30, 60, and 180 seconds, depending on which group the animal belonged to. The response of staying in the entrance chamber had as its consequence the lack of the aforesaid nibble. "Approaching"* had the same consequence. A "contact" (i.e., a touching and immediate withdrawal) had as its consequence a shock and no nibble. The preliminary treatment, consisting of four crossings without shock and with immediate feeding, disposed all the rats to cross. All of them did so at least once.

In this series of experiments, the main satisfier (nibble of food) is intimately connected with the tendency (to cross the obstruction chamber) in the 0 rats, and is much less so in the 15, 30, 60, and 180 second rats. To reach the delay chamber may have been a minor satisfier, since being in it may have formed a connection with the main satisfier and since it meant safety.† There can be no doubt that the food after 0 delay was more potent as a counter force to the

* Putting the head into the obstruction chamber over the grid but then withdrawing without touching the grid.

† The door was closed so that it could not go back on the grid during the period of delay.

shock than the food after 15, 30, 60, or 180 seconds was. But in this case the experiments were not designed to measure learning, so that it is difficult to form a trustworthy opinion concerning the extent to which food with any or no delay strengthened the tendency to cross in spite of the shock. For that purpose a more desirable procedure would have been to repeat the 20-minute test (or a shorter test) several times with the same rats, in each case after the 48-hour absence of food. This would of course have added materially to the labor of the experimenter, and is not suggested as a criticism.

Mrs. Hamilton does report the facts by separate minutes within the twenty. From these records it appears that in all the five groups of rats the tendency to stay in the entrance chamber became relatively stronger as time went on, carrying with it nibbles, shocks, delays, fatigue, etc. The total number of approaches, contacts, and crossings dropped from the first five to the last five minutes as follows:

163	to	92 or 57%	for the	20	min.	0	sec.	rats
227	"	120 or 53%	" "	20	"	15	"	rats
222	"	129 or 58%	" "	20	"	30	"	rats
185	"	152 or 82%	" "	20	"	60	"	rats
168	"	100 or 60%	" "	20	"	180	"	rats

Any further analysis of the course of learning in Dr. Hamilton's experiments is too much complicated by the number of feedings received and other factors to be profitable.

In general, rewarding a rat when he reaches a certain place in a maze in the stock maze-running experiments, is not a promising method of finding out about the strengthening effect of a reward, immediate or delayed. As has just been suggested there is not a contrast between *reward* and *no reward*, in the case of any connections save *reaching the food-box*$\longrightarrow$*entering it* and *reaching the food-box*$\longrightarrow$*keeping out of it*. If the rats are not taught to do the former rather than the latter before the experiment begins, they

learn it very quickly in early trials. That learning will be found to exemplify the Law of Effect clearly and emphatically. But the learning which the bulk of the experiment produces is only remotely connected with the reward and is more truly called learning the topography of the maze than learning to get food. Food comes in any case and is nearly as closely connected in time with the errors as with the right turns.

The reward can do little more for this part of the learning than (1) encourage activity, (2) set the animal toward avoiding merely exploratory activity in favor of directional activity, (3) identify spot after spot backward from the food-box as the place at which you profitably go so and so to get to the food-box, and (4) encourage runs past blind alleys rather than into them. It does the third only rather slowly and does the fourth only on the average and by a small margin. The rat learns the path more or less as a whole, partly because he is by nature a geographer with great interest in places and paths, and partly because he is rewarded (by a quicker attainment of food) for knowledge of it as a whole. If at each correct turn he were given a fraction of his final repast, we could use his behavior to investigate the strengthening effect of rewards. But, as the experiments are now made, all we can expect to learn is that hungry rats will run mazes to reach food and will learn to go to it quickly and by a direct path if they get sufficient relative saving in time of attainment thereby.

The experiment of Roberts ['30] is much more suitable for showing what delay in rewarding a connection does. The situation was confinement in a problem cage. The *right* act was touching a pendulum hanging therein. The reward was (A) the opening of a door into the food-box, and (B) the consequent opportunity to enter and eat. The A segment of the reward was made to act nearly 0,* 5, 10, and 30 seconds. B followed at a variable period according to the rat's familiarity with the course of events.

* Depending on Dr. Roberts' reaction time in pulling a catch.

The record taken was the time between a rat's entrance to the problem-box and its touching the pendulum.

The rats with 0 delay in B learned rapidly and from the first trial. The 5-sec. group learned to touch the pendulum more slowly; the 10-sec. group much more slowly; and the 30-sec. group somewhat more slowly than the 10-sec. group. It would indeed be hard to prove that the 30-sec. group had, within the 69 trials, learned to touch it. All groups save the 0 delay took longer and longer before touching the pendulum in trial after trial up to about trial 15. At trial 14 the 5-sec. group took twice as long as they did at first, the 10-sec. and 30-sec. groups more than twice that long. The reward at first strengthened in their case predominantly the tendency to respond to confinement in the problem-box by progressing to and passing through the door into the food-box. "Particularly noticeable was the tendency to wait in front of the door or to attack and worry it." [Roberts, '30, p. 47.] In the 5-sec. group, the connection between the confinement in the problem-box and hitting the pendulum gained rapidly in strength from near the 15th trial. In the other groups, about 35 and 45 trials were required before the connection between confinement and touching the pendulum got back to its original strength.*

* The connection active in the case of these rats is probably better thought of as *confinement in problem-box* ⟶ *nose around the box and what is therein,* since Roberts reports: "Only in the very last trials and in the first two groups did the animals go directly from the restraining cage to the pendulum with anything like regularity.

"The manner of touching the pendulum varied. Sometimes the animal would do little more than sniff at it. Sometimes he would play with it for a considerable time. Sometimes an animal would slap it in a manner that suggested some expectation of results. In a few cases, but only a few, there seemed to occur behavior that could fairly be described as expectant. The animal would go from the stick to the door, wait there for a time, return to the stick, and again wait in front of the door. In this there was inhibition of random exploring and climbing, and a narrowing of activity to the region of the cage between the stick and the door.

"I was on the watch for stereotyped behavior following the touching of the pendulum. I did not find it. The same animal did not always touch the pendulum in exactly the same fashion. An animal might go from the stick to the door and worry it, the next trial he might busy himself at the rear of the cage, and on the next climb all over the front of it" ['30, p. 48].

In all groups the effect of the first fifteen or more of the rewards was to strengthen the connection which closely preceded the reward in time, whether it was the *right* one or a *wrong* one.

How then did the groups in which it first strengthened a wrong one ever learn? We cannot be sure of our answer without special experiments, but I prophesy that when made these will show that what happened within a few seconds before the door opened was all that was ever strengthened by that fact and that this eventually won out over the sitting by the door and worrying it by some such interplay of forces as is described below.

Consider the 5-sec. rats and their responses to confinement in the problem-box. Consider the latter as a compound of: A, exploration and play in the neighborhood of the pendulum, either on the floor below it or on the wire netting whence it hung suspended; B, play and exploration not in its neighborhood; C, waiting by the door leading to the food-box; D, worrying said door; and E, sitting still elsewhere. Assume that only what occurs from 0 to 2 seconds before the door is opened will be strengthened by that after-effect. Disregard the first three trials during which the rats learned chiefly to go to the door at the sight or sound of its opening. In the next three trials their mean time from entrance to the problem-box to the opening of the door and securing of food was 61 sec. (56 to touch the pendulum + 5 sec. delay). Of this 61 sec. assume that 10 was spent in A and 40 in B and 11 in C. Little or no time was spent in D. There were per trial at this stage 10 chances in 61 that the rat would be, during the last 2 seconds before the door opened, engaged in A, 40 chances in 61 that he would be engaged in B, if his behavior were divided absolutely at random. But since the touch was 5 sec. from the opening, the A activity which included it has a greater probability of being at 2 to 0 sec. from the opening. Set it arbitrarily at 30 in 61 or 1 in 2. The chance of B in these last 2 seconds may be set at 25 in 61, and that of E as

6 in 61 (a rat would be less likely than usual to be sitting still 3 to 5 seconds after he had been playing and exploring). Then in these three trials the reward would be connected equally with A and with B or E. It would connect still more strongly however with going through the door, which was always the immediate predecessor of getting the food and which belonged to it very intimately.

In the next three trials there would be on the average by the Law of Effect a somewhat stronger absolute connection of confinement in the problem-box with A, a little less strong with B, still less strong with E, but a great addition of strength to C and D. The increase of 33 seconds in the time spent before touching the pendulum, was presumably spent in C and D. So in these three trials the chances of A, B, E, C, and D occurring within 0 to 2 seconds before the door opens will, on the foregoing bases, be about 35 in 94 for A, 30 in 94 for B, 7 in 94 for E, and 22 in 94 for C and D together, mostly for E. (Much of the worrying at the door will probably occur early in the time, the rat not playing around until the worrying of the door has been found futile.) A is again strengthened more than B or E. C and D are strengthened very little in and of themselves, but do gain much strength through the inevitable rewarding of the act of going through the door.

This interplay of forces continues until A, which always has an advantage over B and E, also begins to gain at the expense of C and D, since these will rarely happen within 3 to 5 seconds after the touch, and since they lose their belonging with going through the door because they so rarely eventuate in that result. In the actual experiment the waiting and worrying also probably became identifiable and definitely connected with some equivalent of "door stays closed" rather rapidly along in trials 12 to 14 since there is a sudden drop in time before touching (medians 106, 112, 53, 95, 29, 30, 20, 18). Thereafter the A behavior becomes more and more strongly connected with confinement in the problem-box. By our assumptions this must happen; for

if C and D are eliminated and A is done oftener at the beginning than B in the 2 seconds before the door opens, it will get more strengthening, and will be done still oftener and so on.

The numerical estimates made above may be wide of the mark. The essentials are that the kind of behavior found at the touch is likely to be found 3 to 5 seconds before it and after it; that the sitting by the door and worrying the door rise in strength as secondary products of a strong tendency to go through that place, and then decline in strength because they are in and of themselves rarely or never rewarded, and probably also because of a frequency connection with "door stays closed" supplemented by such identification of the act and the fact as rats are capable of.

It is very significant that few of the 5-sec. rats, and these late in the training, seemed to attack the pendulum itself definitely or with expectation. The connection which was strengthened was not with that particular act (which could only by the rarest chance occur within a second of the opening of the door), but with a certain sort of exploration and play, which could be in action just before the door opened. These same principles may be adequate to explain the much slower learning of the rats with 10 sec. and 30 sec. delay. Even there we may not have to suppose that the reward acts on anything more than 1 or 2 seconds preceding it. The fact that the rise in the time between entering the problem-box and touching the pendulum is of the same general sort but higher and more protracted and that the fall is of the same general sort but much slower supports this expectation.

Yarbrough ['21] was not concerned with the influence of incentives as such, but with the general problem of the connection of two events separated by an interval. One of these events was a painful electric shock. After the response of turning around and going back had been firmly connected with this by ordinary methods, a buzzer was

sounded at intervals of 0, 1, 2, 4, and 6 seconds before the shock was given. In the last four cases, if the animal turned and went back at the buzzer he received no shock. Learning to do so was rapid for the intervals of 0 and 1, but very much slower for the intervals of 2, 4, and 6. The inferiority was about equal for 2, 4, and 6.

In all cases the above concerned only 70 percent of the trials. In 30 percent there was no shock or buzzer and the animal got to the goal more quickly by not turning around and going back. The options and consequences were as follows:

No buzzer, go ahead, reach goal quickly
No buzzer, turn, go back, reach goal much later
Buzzer, go ahead, receive shock, and reach goal late
Buzzer, turn, go back, avoid shock, and reach goal late.

Learning meant responding to no buzzer by going ahead and responding to buzzer by turning back.

The differences in learning can be accounted for as due to the influence of the delay upon the "belonging" of the turning with the buzzer, or as due to the delay of the punishment attached to not turning at the buzzer, or as due to a mixture of the two. The third is the most probable. One thing is certain, that the shock influenced what came 1 second before it very much more than what came 2 seconds or more before it.

The results on delay in feeding obtained by Borovski ['30, p. 554] are in harmony with those of Hamilton and Roberts.

Nobody has ever demonstrated a case where a satisfier has strengthened a connection remote from it in time, and nobody has ever demonstrated a case where a satisfier has failed to strengthen a modifiable connection which immediately preceded it and to which it belonged.

The facts stated in the discussion of Hamilton's results demonstrate that the order of elimination of errors in maze-running need not militate against the hypothesis that

satisfying after-effects strengthen connections. Nor do they, in fact. On the contrary they are just what would be expected by it. What is rewarded? First and foremost, going in at the entrance to the food-box rather than retracing from it or passing it by. And the rats do learn first of all to eliminate passing or retracing at this point. Second, to keep going save when in reach of the food. The rat is, on the average, going oftener than staying still just before he reaches the food. Later, he is oftener going than staying still just before he reaches the food-box entrance (which by then has acquired satisfyingness). So we should, by the Law of Effect, expect him to increase running in contrast to staying still. This also he does.

In the early trials nothing else happens within a second or two of the reward; the connections of reward and no reward with all else are the same. As training continues and the topography of the maze becomes better and better known, there may occasionally be a quick dash from a point near the entrance to the food-box to that entrance, and the satisfying after-effect of this quick dash may be near enough to the connection to strengthen it. So there should, on the average, appear tendencies upon reaching a point near the food-box entrance to decrease hesitation and exploration and dash on and in. Such do occur. This may involve elimination of the blind alley nearest the food-box, and, on the whole, entrances to it should consequently be eliminated sooner than entrances to others. They are.

Warden ['29], who has taken pains to make the blind alleys of equal length and otherwise equally difficult except for their temporal relations to the attainment of food, finds that the number of trials required for elimination of the blind alley nearest the food-box entrance is less than the number required for the next nearest in every case and less than the average for all others in the maze in question in every case. The facts are, for mazes with 2, 4, 6, 8, and 10 blind alleys, respectively:

	Next to Last	Last
Maze with 2 blind alleys	14.2	11.4
4 " "	6.1	4.3
6 " "	5.8	2.7
8 " "	4.3	3.8
10 " "	8.5	0.4*

	Av. of Others	Last
Maze with 2 blind alleys	14.2	11.4
4 " "	12.3	4.3
6 " "	7.4	2.7
8 " "	8.8	3.8
10 " "	8.5	0.4*

Hubbert and Lashley ['17], in the case of one of their two types of error, find the number of trials less for the place nearest the food-box than for the next to the last or the average of the others. In Hubbert's earlier work ['15] the difference was very pronounced. The average number of trials required for elimination for each of the four groups of rats was much less for the last blind alley than for the one just before it or for the average of all before it. The averages are:

	Averages		Medians	
	Next to Last	Last	Next to Last	Last
Group 1	16	4	14	3
" 2	14	3	9	3
" 3	18	8	13½	5½
" 4	25	16	19½	5½

	Av. of Others	Last
Group 1	19	4
" 2	18	3
" 3	26	8
" 4	26	16

Vincent ['15] also found a quicker elimination of the last blind alley than of the next to the last or the average of all save the last in all four cases.†

* The identity of these two records is not due to any error.

† The criticisms as to method made by Lashley can hardly be valid as between the last and the next to the last alley.

The facts are:

Next to Last	Last	Av. of Others	Last
16	11	16½	11
6	2½	9	2½
14	9*	11½	9*
10	8*	10	8*
8	2	18	2
10	2	20	2

Warden found in his Experiment I quicker elimination of the last than of the average of the others (6.05 and 5.53), though the next to the last was quicker (3.86 and 5.53).

The last is thus more quickly eliminated than the average of the others in seventeen series out of eighteen, and is eliminated more quickly than the next to the last in sixteen out of eighteen.†

As the satisfyingness shifts back from eating to reaching the food, then to reaching the entrance to the food-box, and then to reaching an earlier point whence progress to the food is safe and easy, there may be an attachment of satisfyingness to neglect of the second blind alley, and so on back, but this will be progressively rarer and later in the course of training. As we have no means of telling how far back this shift went in the case of any of the animals in any of the experiments cited, we cannot prove that when it had so shifted it thereafter strengthened the connection that preceded it by a second or two. Apart from such attachment of satisfyingness to reaching certain positions, the animal learns the rest of the maze, not by the presence versus the absence of any immediate satisfying after-effect, but by

* These records from mazes in which an olfactory trail was laid may well be omitted from consideration.

† The number of trials with the maze as a whole that are required to eliminate a certain error at one place in it is a very clumsy measure of the speed of connecting the situation of arriving at that spot with the response of going from it along the right path. The number of errors is better, and perhaps the number of errors minus those due to retracing is better still. Using these as criteria where the data are available, one finds the quicker learning of the right response at the last blind alley even more pronounced than by the "trials" criterion.

the fact that certain responses are followed on the average by quicker attainment of the reward, and by forces with which the food reward has nothing to do.

The quicker attainment of the reward obviously is a consequence of any right response regardless of its location and so will strengthen one as much or as little as another.

That part of the learning of rats in maze-running consists in the acquirement of topographical knowledge of the maze irrespective of the reward given at the food-box is proved by such facts as these: Rats having 20 minutes of exploration of a maze with no reward before training with reward began profited from the exploration [Lashley, '18]. Rats not hungry made their way 61 times through a maze to their home cage where food awaited them, without any decrease in time or errors. When thereafter they were put at the entrance of the maze when hungry, a very few trials gave them mastery [Szymanski, '18]. Hungry rats trained without reward for two or six days improved hardly any during these, but after reward was introduced on day three or seven, they improved enormously, much more than one application of the reward could account for [Blodgett, '29].

The forces other than the food reward which teach the rat the topography of a maze, so that, if he wants to, he can quickly learn the way to the food-box are of little importance for our argument.*

Joseph Peterson ['20] finds that human subjects learning a maze by choosing alternatives at each point and being sent back to the beginning when their choices are wrong, eliminate errors in choices of paths nearest the goal first, and more and more slowly the greater the remoteness from the goal. But these results are not appropriate for use as an answer to our present problem. The rewards and punishments in such learning by human subjects are not the same in character or incidence as those in maze-running by rats. Nor are the situations and responses the same.

* The reader who is curious about them may consult Hunter, '29, Maier, '29, and Dashiell, '30 and the references given by the last named.

As soon as a person realizes that a certain after-effect in the form of the experimenter's *Choose N or V* means that he is sent back to the beginning, that after-effect may become annoying and any other after-effect than it may become satisfying, and there may be reward and punishment at each choice.

Those who expressed disbelief in the efficacy of the after-effects of connections should in fairness and logic have duplicated the experiments where learning seemed to consist largely in strengthening by satisfying after-effects, but with these omitted and with whatever they regarded as the efficacious fact put in their place. This they never did, but a part of it was finally done by others. There have been recently a number of such studies.

Simmons ['24] found that, after the first three or four trials (when the exploratory interest was presumably strong), rats showed little or no reduction in time or errors in running mazes, unless they were rewarded for quicker running. The reward was getting to food or a mate more quickly. Bread and milk was more potent than sunflower seed as a food reward. Return home added to the potency of the food reward, but had little or no potency by itself alone.

Blodgett ['29] ran rats in mazes with and without food reward, other conditions being equalized so far as possible. "The experimental groups (II and III), so long as they were without reward, did very much worse than the control group (I). In fact the curves for Groups II and III stayed almost horizontal until after the day . . . when food was introduced" ['29, p. 120]. In a different maze in which speedy access to the food was obtainable only by choosing shorter or longer alleys (retracing being prevented by closing a door behind the rat after each choice), a control group, rewarded after each run, reduced "errors" rapidly, whereas the experimental group, run without reward for 16 days, reduced their "errors" hardly at all.

Comparing the averages for successive sets of four days, we have:

Rats with reward	11.3	7.0	4.3	1.5
Rats without reward	11.3	9.0	10.0	9.3*

Elliott has given further evidence of the potency of the reward, and of the fact that its value lies in its satisfyingness, or "reward-value." "Water has reward-value only for the thirsty animal" ['28, '29, and '29a].

Grindley ['29] has shown in the case of chicks, that the greater the satisfyingness, the more rapid the learning.

Williams ['29] has shown that when a satisfier is inserted for a few trials in the course of learning, rats improve much more during those trials than before or after them.

Sharp ['29] and Bruce ['30] have shown that omitting the resulting satisfier after a maze habit has been nearly or quite formed disturbs the habit greatly. The rats, indeed, seem to be stimulated by finding no food at the accustomed spot to go anywhere else rather than there. They take more time and diverge oftener from the direct path than at the very beginning of training. Repetition without the reward does not bring the habit back. "Removal of the food incentive introduces a marked degree of disintegration into a maze habit, which practice within the limits of our experiment reduces but little." [Sharp, '29, p. 422.]

Ligon ['29] shows that the presence of a food reward facilitates learning and also that the correlations between (a) the amount of activity during twenty minutes' confinement in a revolving cage immediately preceding the experiment and (b) the time in the maze (an inverse measure of success in learning) are what would be expected if the food reward strengthened the tendency to keep moving and to move rapidly in the maze. For rats running to an empty cage, the correlation is zero, but for hungry rats running to a food reward with the aid of a buzzer sounding in the food box r_{ab} is —.63. The correlation between activ-

* Computed from Tables 6 and 7 of Blodgett ['29, p. 132].

ity and speed in traversing the maze is then +.63. As Ligon says, "... the rat has a certain amount of activity as indicated by his record in the revolving cage. This activity may be expended in random movements in the maze or in running the maze. If this activity is spent in running toward the food cage, the correlation between the activity and the speed of running will be high. If, on the other hand, the activity is spent in random movements, the speed of getting to the food cage will be a matter of chance and the correlation between this time of running and the activity will be low. If the law of effect be true, then, there will be a direct relationship between time and activity for that group. The above data seem ample evidence in favor of such an hypothesis" ['29, pp. 67f.].

In these maze experiments, there is a mixture of learning to be able to go quickly to a certain place and of learning to wish to go there (or to try to go there, or to be set to restlessness and motion when not there and to peace and rest when there, or to tend to go there, or whatever better expresses the fact). Experiments with the multiple-choice apparatus, or discrimination-boxes, or problem-boxes, or the like, freed from the elaborate topographical learning, would be somewhat more instructive. But the maze experiments certainly prove that the alteration or omission of the satisfying after-effect has crucial results upon learning.

Evidence from memory. Some have argued that if satisfying after-effects strengthen connections whereas annoying after-effects weaken them (by strengthening some other connection with the situation or otherwise), we ought to remember satisfying and forget annoying experiences. The rather slight difference in memorability found on the whole between pleasant and unpleasant stimuli would then be evidence against the Law of Effect.*

These facts are, however, not strictly pertinent. The Law of Effect would not lead us to remember experiences

* Meltzer ['30] provides a convenient summary of the findings of some fifty experimental and critical studies.

that were pleasant and forget experiences that were painful, but to remember experiences that have been *pleasant to remember*, and forget experiences that have been *painful to remember*, a very different matter. "Nessun maggior dolore que ricordarsi dal tempo felice nella miseria." Conversely, to be reminded of the pains of past diseases is an obvious delight to many persons, who describe them with gusto.

How far people do recall those matters whose recall gives them satisfaction rather than those whose recall annoys them has not, to my knowledge, been measured.* But there is probably a large balance in favor of the former, the original intensity and frequency being equal. In what they relate to others, there is an enormous balance of reports of being successful, saying clever things and the like, over reports of failure and stupidity (as viewed by the reporter). This is specially observable in naïve individuals and little children whose reports are most like their memories. In daydreams and building castles in the air, which may be expected to illustrate the same general laws as recall, people make themselves content rather than wretched nine times out of ten. If we allow for the satisfyingness of gaining attention and sympathy, the number of cases of recall of what is on the whole painful to recall will be reduced.

We should note also that certain perverse tendencies to recall facts the contemplation of which is painful, may be accompanied by subtle and morbid satisfaction. These facts may serve as an excuse for indulging in some cherished practice, or may maintain the individual's self-respect, or may protect him against even more painful thoughts.

* The nearest to such a measurement which I have found is by Zeigarnik, who reports ['27, p. 77] that boys who failed in a crocheting task remembered the task among others which they had done, but that girls who failed often forgot it. Zeigarnik found in general that subjects often forgot those tasks in which they had failed and *felt ashamed of failing*. Only 32% of such were remembered as compared with a general average of 68%.

Still more important for the general issue are the cases where certain acts evoke memories of experiences which are pleasant or painful to remember. Everyone must agree that acts which lead to satisfying memories are favored. The mother looks often at the picture which reminds her of the child's early love and charm. We keep and examine mementos of our pleasures and triumphs and destroy or avoid mementos of the occasions when we suffered failure, scorn and loss of self-respect.

The Law of Effect does not assert that man tends in any special way to suppress painful and evoke satisfying memories, but only that when his response to a situation is the recall of some past experience or fact the connection between that situation and that response will be influenced by its after-effects in the same manner that any modifiable connection is.

Snoddy argues that the satisfyingness of the right responses in mirror-tracing of a path cannot cause the improvement because "On those sides of the star (the vertical sides) where every movement is followed by the feeling of satisfyingness, practically no improvement takes place from the first circuit to the end of the practice: the improvement occurs on the difficult oblique sides" ['20, p. 33].

This is not an argument against the Law of Effect. If on the vertical sides right and wrong tendencies are equally satisfying, they would be equally strengthened, with the result of no improvement. It is not the average general pleasantness of easy sides versus hard sides that would cause improvement, but the relative satisfyingness of the right and the wrong response to any one spot within any side. To argue against the influence of satisfying after-effects, Snoddy should have arranged matters so that the *right* movements would at times have been made annoying. If, for example, he had arranged his apparatus so that at certain sides the subject thought he was going straight only when he went zigzag and vice versa, he would have found that the satisfyingness was potent.

§ 4. General criticisms of the law of effect

The important criticisms of the Law of Effect are (1) that the physiology of the action of the after-effects in strengthening connections is not known, and (2) that it requires back action upon a connection which has ceased to operate and is inaccessible.

I shall use a statement by Carr ['14] as if his criticisms of what he called the "algedonic theory" were applied to the general theory of the influence of the after-effects of connections. I am doubtful whether Carr intended his criticisms to be so applied. For in a recent publication ['30] he states clearly and emphatically his acceptance of the Law of Effect as a fact.*

The objections quoted below are such as are often made to the Law of Effect and are made more clearly in Carr's statement than elsewhere. So I use them, cautioning the reader that Carr may not himself regard them as valid against the hypothesis that the satisfying after-effects of a connection do strengthen it.

Carr ['14, pp. 164 f.] objected to the algedonic theory that "Many acts are learned which are distinctly unpleasant during the early stages at least" [p. 164]. But it is the *consequences* of the connection, not the act itself, which are supposed by the Law of Effect to be satisfying. He objected further that "the algedonic theory meets the difficulty of an objective criterion of these subjective conditions" [p. 164]. But our criterion *is* objective, being that *A satisfying state of affairs is one which the animal does nothing to avoid, often doing such things as attain or preserve it.* He objected further that "Any theory is in duty bound to attempt some rational connection between its explanatory principles and the phenomena of selection. The algedonic theory meets difficulty in this respect. The affective processes must be so conceived that they can exert some causal influence upon the sensori-motor activities involved"

* See the note on p. 472.

[p. 165]. But reward is no worse off in this respect than frequency or recency or intensity, except for the time relations. How they exert a causal influence nobody knows.

The following statements by Joseph Peterson ['27] attach to early statements by the writer ['98] a mystical meaning which was not then intended and which, I think, was clearly negatived by later statements ['13]. I add comments in brackets.

"Association early showed its weakness in the experimental psychology of learning where it was necessary to invoke a stamping in effect of pleasure on 'successful' acts, and a stamping out effect of pain on 'wrong' acts. Thorndike, who employed this conception, early recognized the difficulties involved in the fact that the pleasure would thus have to be retroactive through a chain of random activities, giving emphasis to those only which led up to the pleasurable end-result." [This is inaccurate. I did not say or think that the satisfying after-effect would have to pick out certain activities far back in a chain, but only that it would have to act on the response immediately preceding it.] "But even with such mysterious guiding powers ascribed to pleasure this hedonistic theory had to explain how elimination of errors comes about. Why was not the whole series of random acts which finally led up to the pleasurable end-reaction fixed *as a whole*, since pleasure resulted from the whole series as it occurred?" [The strengthening is not, save secondarily, of what *causes* the after-effect, but of what closely precedes or accompanies it and belongs to it.] "Aside from these difficulties was, of course, the clear implication of an enigmatic dualism. In Max Meyer's terms, a ghost had been introduced to do what could not be understood and accounted for on the laws of nature; it was a real unconditioned force as objectionable and as unfounded in facts as any other faculty." [But there is nothing unconditioned or ghost-like about a satisfying state of affairs. Getting food, getting freedom, getting praise, hearing *Right* are typical satisfiers.]

It may perhaps be objected that the principle of "belonging" is mystical, so I note here that it has, to my mind, an absolutely material basis, its neural equivalent being temporally uninterrupted conduction from one locus to another. If, for example, there is, during time T, conduction from A to X, from B to Y, and from C to Z, X will "belong" to A, Y will "belong" to B, and Z will "belong" to C. The truth of the fact of belonging is, however, entirely independent of this physiological explanation.

We have nothing in general to add to our previous discussion of the physiology of the Law of Effect, and of the possibility that a connection leaves something on which the satisfyingness of the next instant can and does act.

In an early description of animal learning ['98], the writer used the word "random" of the multiple responses displayed by an animal, to the same external situation, and various writers have objected that learning does not and could not, save at an infinitely slow rate, come by selection from absolutely "random" responses. So Dexler ['26, p. 217] writes of learning "through chance selection of the successful impulse and its association with the problem situation (Thorndike) in which entirely incalculable chance (*ganz unberechenbar Zufall*) plays a decisive rôle." Similarly H. L. Hollingworth ['28, p. 115] states "there are no 'random movements,' and no experimental animal ever acted at random."

The context of the original statement makes it obvious that the randomness of a chance selection from all the responses of the animal's entire repertory was not meant.

Thorndike ['13, pp. 135-149] took pains to show that "the actions are 'chance' ones only in the sense that observation of the external situation alone cannot predict them nearly so well as it can the actions of eating, flight, or attack," and that "Whatever use rhetorical necessities may direct of the phrases 'random responses,' 'general mental and physical activity,' 'varied reaction' and the like, the student of human behavior must bear in mind just what the

peculiar limited randomness generality or variety is. What it is I have tried to describe in the course of this inventory'' [p. 149].

Critics of the doctrine that learning is a selection from responses made by pure chance are criticizing a doctrine which, if anybody ever held it, certainly plays no part whatsoever, directly or indirectly, in supporting any of the doctrines of this volume, or of present connectionism.

§ 5. Substitutes for the law of effect

Watson's latest explanation of selective learning is substantially that offered by Stevenson Smith in 1908 ['30]. It is as follows: "To make the whole process a little more concrete, let us put in front of the three-year-old child, whose habits of manipulation are well established, a problem box—a box that can be opened only after a certain thing has been done; for example, he has to press inward a small wooden button. Before we hand it to him, we show him the open box containing several small pieces of candy and then we close it and tell him that if he opens it he may have a piece of candy. This situation is new to him. None of his previously formed manipulation habits will completely and instantly work in this situation. None of his unlearned reactions will help him very much. What does he do? That depends upon his previous organization. If well organized by previous handling of toys, he goes at the problem at once—(1) he picks the box up, (2) he pounds it on the floor, (3) he drags it round and round, (4) he pushes it up against the base-board, (5) he turns it over, (6) he strikes it with his fist. In other words, he does everything he has learned to do in the past in similar situations. He displays his whole repertoire of acts—brings all of his previously acquired organization to bear upon the new problem. Let us suppose that he had 50 learned and unlearned separate responses at his command. At one time or another during his first attempt to open the box, let us assume that he displays, as he will, nearly all of them be-

fore he pushes the button hard enough to release the catch. The time the whole process takes, we will say, is about twenty minutes. When he opens it, we give him his bit of candy, close up the box and hand it to him again. The next time he makes fewer movements; the third time fewer still. In 10 trials or less he can open the box without making a useless movement and he can open it in two seconds.

"Why is the time cut down, and why do movements not necessary to the solution gradually drop out of the series? This has been a hard problem to solve because no one has ever simplified the problem enough really to bring experimental technique to bear upon it. I have tried to explain on what we may call a *frequency* and *recency* basis, why the one movement finally persists whereas all the rest die away. I think I can make clear to you what we mean. Let us designate each of the separate acts of the three-year-old by a number. We will designate the final act—pressing the button which opens the box—number 50. Then on the first trial of the 50 acts will occur (and many may appear more than once), let us say, in chance order:

47, 21, 3, 7, 14, 16, 19, 38, 28, 2, etc..................50

On the second trial:

18, 6, 9, 16, 47, 19, 23, 27, etc..................50

On the third trial:

17, 11, 29, 66, 71, 18, etc................50

On the ninth trial:

14, 18, etc.......................50

On the tenth trial and all succeeding trials:

50

"In other words, number 50 tends to come earlier and earlier in the series and by doing so there is less and less opportunity for other movements to appear. Why? On our premise we can see that response number 50 is the only one that occurred on each and every trial; that is, the environment in the shape of the person conducting the test arranges the series in such a way that 50 has to be the end

of the series—the infant then gets food; the box is closed and is handed to him again. Act number 50 is therefore the one most frequently repeated—more frequently, that is, than any of the other 49 acts.

"Again, since act number 50 is always the last response in the previous trial, there is some reason for believing that it will appear sooner in the series of acts on the next succeeding trial. This is what is called the factor of *recency*." [J. B. Watson, '30, pp. 204-206.]

The facts of Chapters IX and II have shown that the selected response is by no means always more frequent than any other one response in the early trials, and that even if it were, it would not thereby wax at the expense of the less frequent. We may note here in addition that records of learning show on the average a relative strengthening of the rewarded connection from trial 1 to trial 2, though by Watson's explanation there *never* can be a greater frequency for the rewarded connection in trial 1 than for any other one not-rewarded connection, and will often be a smaller.

Carr ['14] made a serious and thoroughgoing attempt to find the "factors which favor the retentive development of the successful act at the expense of the many failures. The principles are relative recency, relative frequency, and relative intensity." He applies these to three classes of problems. I quote his argument in full, inserting comments in rebuttal in brackets.

"For our purposes, all animal problems may be divided into three classes: (1) that involving a series of simple acts directed toward the stimulus, the final one of which is necessarily the successful one. This type is illustrated by a problem box opened by pulling upon a cord suspended in front of the door. (2) The second type is represented by the maze or a complex problem box involving a fixed series of lever manipulations. The successful act is a complex whole composed of elements which were originally separated from each other by many useless acts. The

process of learning involves the elimination of the useless and the serial coördination of the various elements, only one of which can be the final one of the series. (3) The third type deals with the inhibition of some instinct or habit.

"All three principles are effective in the first problem. The successful act tends to occur more frequently during the learning than any of the useless acts." [But in the first stages of learning this is not so. The later greater frequency is an effect, not a cause, of selection. Moreover we have shown in Chapter II that there is no tendency for the frequent response to wax at the expense of the less frequent.] "The successful act must occur in every trial, while as a matter of fact any useless act on the average does not occur in more than half of the trials. It is possible, however, for some error to be repeated a number of times in one trial. Since the successful act can occur but once per trial, it is thus possible for some error to be repeated throughout the learning process more frequently than the successful act. Why should not this error be selected? Our answer is that this fixing of useless acts does as a matter of fact often occur in both animal and human learning, and the phenomenon supports rather than disproves our conception. As to the final elimination of such useless acts, we are forced to contend that they never would be eliminated on the basis of frequency alone. Their final elimination is due to the coöperation of the other factors.

"The successful act is intensified and accelerated by its sensory consequences to a greater degree than is any other act. This act possesses a number of peculiar and distinctive sensory consequences. The string in common with most other parts of the apparatus offers some resistance to attack but its behavior is unique in that it suddenly gives way to the pull. The sudden opening of the door is a surprising and unusual visual and auditory result that not only attracts attention but often even excites a certain timidity.

After entrance, the box is sensed from the inside—a rather striking effect to those animals equipped with some disposition either to avoid or to seek such enclosures. The intensity of the food stimulus is increased in a more pronounced manner than heretofore, while the new elements of taste and mouth contact are added. The final and most important sensory consequence distinctive of the successful act is the alteration of the hunger aspect of the sensory situation. That the successful act is characterized by distinctive and important sensory effects is evident from the fact that the only real criterion of a success as opposed to an error or failure depends in the last analysis upon the nature of the sensory effects of those acts.'' [All this is true of some responses that are selected for connection with the initial situations, but there can be selection of a response where its sensory consequences are less intense than those of the weakened or eliminated responses. For example, in many of the multiple-choice experiments of Yerkes and his pupils, a peaceful, uneventful walk to food followed the selected response, whereas a very peculiar and distinctive electric shock or exciting and irritating confinement followed the weakened response. In all cases it seems to be the satisfyingness of the sensory consequences rather than their peculiarity, distinctiveness, surprise, unusualness, or intensity, that strengthens the preceding connection. Furthermore, why should these sensory consequences have power to intensify or accelerate the act which precedes them and satisfying consequences lack it?] ''Not only does the successful act result in novel and significant sensory changes, but there is evidence on the motor side of their stimulative efficiency. The final series of acts beginning with the downward pull on the string represent the maximum of tension, excitement, vigor, decisiveness and acceleration. This change in the character of the animal's behavior is very apparent and striking though rather difficult to measure in any quantitative terms.'' [This I think occurs chiefly *after* the act has been found to produce satisfaction. In the dogs

and cats with which I myself experimented, the first appearances of the successful acts were far from representing "the maximum of tension, excitement, vigor, decisiveness and acceleration." Attempts to squeeze through openings fitted that description much better.]

"The successful act is necessarily the final one of the series—the most recent one. The effectiveness of this factor can naturally be inferred from human experiments. Any explanation of its efficiency is more difficult, but this difficulty obtains for the human realm as well. Although we are concerned more with matters of fact than with explanation, we may mention three possibilities. The successful act stands in a closer temporal relation to the subsequent trial than does any of the failures, and we can assume that the retentive effect of any act is inversely proportional, other things being equal, to its age. This disparity of age, however, would seem to be negligible except in those problems where a number of trials are given in immediate succession." [And since a considerable time interval seems rather beneficial to selection, recency is a principle of very minor importance.] "Recency may also be interpreted as temporal contiguity to the food stimulus. In this sense the factor would seem to be a special case of the intensity principle. Again, the successful act may be favored because it is the *final* one, rather than an act which is followed by further activity. It is known that any activity interferes with the gradual setting or fixing of the retentive effects of any immediately previous act. The retention of all useless acts is thus retarded by the necessity for further activity, while the final or successful act is relatively favored by the absence of such subsequent distractions." [I shall deal with finality and freedom from inhibition elsewhere, noting here only that in multiple-choice learning of certain sorts the selected connection is no more final than any other.]

"The maze is taken for the second type of problem. The effective factors are frequency and intensity. During the

first trial segments of the true path will be traversed more frequently than the cul de sacs, and this disparity must rapidly increase from trial to trial." [No. See Chapter II.] "Let X be a blind alley, interpolated between two segments of the true path, A and B. Let the animal be running forward through segment A leading to B and X. Since the probabilities of entering B or X are even in the long run, and X can be entered on the forward journey only through A, it follows that A will tend to be traversed twice as frequently as X. What is true for A and X will hold for any segment and its succeeding cul de sac on the forward journey. The same relation will also apply for any returns toward the entrance box. In the latter case, however, the ratio of frequency in favor of the true path will be increased owing to the fact that an animal in these returns very rarely leaves the true path." [But later work has shown that all this is not true in general.]

"The usual distinction between the true and the false paths in a maze is wholly meaningless from the standpoint of a learner, be he animal or human. Such a distinction can arise only as the maze is mastered. From the standpoint of the immediate sensori-motor situation in which the animal is placed, the true path and the cul de sacs are to be distinguished from each other on the basis of the degree to which they impede or encourage the animal's activity. A blind alley is but a sensory obstacle or impediment to the animal's activity; it means hesitation, caution, investigation, or disastrous sensory consequences. The true path presents fewer obstacles; it offers greater encouragement to freedom, continuity, rapidity, and vigor of motor expression. The difference is merely one of *degree*. The blinds check, thwart, and suppress activity more than does the true path, while the latter encourages and facilitates activity more than does a blind alley. The principle of relative intensity is here effective; acts are selected or eliminated according to whether the sensory consequences tend to facilitate and intensify them on the one hand, or to

disrupt and suppress them on the other." [All this fails if certain sorts of tasks are used. If the maze, for example, consists of choices between short and long paths, the short paths will be selected, though the long ones have equal freedom and continuity and vigor of motor expression, and more activity. The superiority is then in the quickness of getting food, not in the intensity of the act or of its sensory consequences.]

"For the third problem, let us assume that an animal is reacting positively to some food object sensed at a distance. Let the conditions be so arranged that any contact with the object will result in an electric shock. The animal thus comes to the problem endowed with two ready-made connections, a positive response to the object, and an avoiding reaction to the pain stimulus. We shall term these connections S-M, and P-A, respectively. The functioning of the first tendency inevitably results in the arousal of the second and the two are brought into conflict. This second disposition is necessarily the stronger or it would not dominate in the conflict." [Is it the stronger, or the less annoying?] "In this situation, the second act A becomes connected with some sensory aspect X of the object, and the new connection X-A is formed. The only essential requirement of this stimulus X is that it be sensed at a distance. The further task of learning now consists in the development of X-A to a point where its functional efficiency is greater than that of S-M. Its strength does not need to exceed that of P-A, because the successful functioning of X-A will prevent the animal from receiving the pain stimulus. All three of our principles favor the connection X-A over that of S-M. The avoiding response is the more recent." [This is of little consequence if the intervals between trials are long.] "The retentive development of the positive response is interfered with by this violent irruption of the pain stimulus and its motor results. The latter disposition is, however, subjected to no such distractions. The negative response is the more intense and vigorous one. Be-

cause of its greater recency and intensity, the resulting disposition is so susceptible that it is likely to be aroused and become connected with almost any opportune stimulus connected with the total situation.'' [But if the X⟶A reaction is not productive of after-effects that are relatively satisfying, it is not selected, no matter how intense and vigorous it is. If, for example, X⟶A avoids the shock from contact with the object but gives the animal a still worse shock when it draws back, will X⟶A displace S⟶M?] ''What this stimulus shall be and the number of trials necessary to establish an efficient connection will depend upon the nature and intensity of the possible stimuli and the organism's capacity to sense them. After the new connection approximates the old in functional strength, the factor of frequency will become operative and assist in the final stages of the elimination'' ['14, pp. 159-163].

Carr has done as well probably as can be done with these principles. They are not adequate for these types of learning; and they work even less well with selection in multiple-choice learning. Moreover, as we have shown in Chapter IX, when frequency, recency, intensity, and finality are equalized, the difference between the various responses to the same external situation being that one is satisfying and the others are not, we have indubitable selection of that one.

It seems probable from Carr's most recent statement ['30] that he would not now regard recency, frequency, intensity, and finality as adequate principles. I quote this statement in the accompanying note, but I retain the earlier quotation because it is such good defense of these principles.*

* ''A successful act is one that leads to certain resultants which we call successful, while the other acts bring about results that we term unsuccessful. An act is thus selected because it attains successful results or effects, and the other acts are eliminated in virtue of their unsuccessful results or effects. This is the law of effect. Acts are either selected or eliminated in respect to a given problematical situation according to the character of their resultants in reference to that situation. Successful resultants tend to eliminate those acts which were their causal antecedents. This proposition, to my mind, is a factual

Holmes has extended Hobhouse's observation that certain annoying after-effects of response A produce a response B which counteracts A, to a general theory. He writes: "In the reinforcement or stamping in of a reaction to a particular stimulus that brings pleasure, it certainly seems as if pleasure or its physiological correlate in some way serves to cement more firmly the association between the stimulus and the response. Let us consider, however, the case in which the chick pecks at a caterpillar which has a good taste. The presence of the caterpillar in the mouth excites the swallowing reflexes; in the presence of a similar caterpillar the pecking response is made more readily than before, and whatever hesitation there may have been at first disappears. Is not the difference from the pain-response due to the fact that there is an organic incompatibility between the first and second responses in the pain response, while there is an organic congruity or mutual reinforcement of these responses in the other? Pecking and swallowing form the normal elements of a chain reflex; when one part of the system is excited it tends to excite the rest, to increase the general tonus of all parts concerned in the reaction.

"According to the view here presented, whether a particular response to a stimulus tends to be repeated more readily or discontinued, depends not upon the peculiar physiological state which may be produced in the brain, but upon the kind of responses which the stimuli brought by the act call forth. If an outreaching reaction becomes coupled with a withdrawing response the result is inhibition. If the reaction, on the other hand, brings stimuli which produce congruent reactions the association formed with these latter reinforces the first reaction. The pleasure-pain response then resolves itself into the formation of

statement of a demonstrable contingent correlation of two independently observable phenomena, viz., success and selection, and it must be accepted as a fact irrespective of any difficulties that may be encountered in explaining it." [Carr, '30, p. 207.]

associations. Withdrawing and defensive responses are usually initiated by pain-giving stimuli, and the instinctive or random movement which brings painful stimulus is inhibited under similar conditions in the future, not because of the pain of its physiological correlate, but because it comes to be associated with a withdrawing or defensive, and hence an incongruous or inhibitory reaction. Pleasure and pain thus interpreted have no mysterious power of stamping in or stamping out certain associations. Whether the result is reinforcement or inhibition depends on the way in which a reaction and the secondary responses resulting from the situation in which the organism is thereby brought, happen to harmonize'' ['11, pp. 177f.].

Joseph Peterson writes: ''Elimination of random acts not favoring the dominant determining tendency seems to be brought about somehow by interference through conflict of different interacting processes. . . . The more consistent acts survive . . . and the less consistent ones are eliminated . . . because of a greater degree of mutual facilitation by the several part processes in the one case and of inhibition in the other'' ['22, pp. 384f.].

There are two main difficulties with these and with all other reductions of the influence of after-effects to harmony or congruity *versus* inhibition. They do not explain the great differences which appear between satisfying consequences and indifference. They do not explain the difference between the thwarting of some craving and the appeasing of that craving where there is no counteracting or harmony save that of the thwarting and appeasing. In particular, they do not explain the learning in those discrimination tests, problem-boxes, and multiple-choice experiments where there is no secondary response that confirms or counteracts the first reaction. An animal, for example, goes into door A and eats and goes on to his resting place. He goes into door B and does not eat and goes on to his resting place. Nothing confirms or counteracts anything by harmony or incongruity. Eating and not eat-

ing are equally congruous with going in through a door. They differ only in their satisfyingness, and change in their power over learning according to the animal's desire for food. Similarly, hearing *Right* and hearing *Wrong* are equally congruous with any act. Many of the experiments of Chapters IX and X were so arranged that congruity is equal, and so that no counteracting secondary responses could be made.

Woodworth accepts the influence of lack of "success" in leading to an avoidance of the acts which lack it (in connection with the relevant situations, of course). He has used freedom from inhibition and greater intensity derived from the dammed-up energy released by the consummatory reaction, as substitutes for direct action of the satisfying after-effects. This latter is an advance over a vague claim that the successful response or connection is more intense, but does not seem adequate as a general explanation. I quote the relevant passages with some comments on this new form of the intensity doctrine.

"In the first place, we must assume in the animal an adjustment or determination of the psycho-physical mechanism toward a certain end. The animal desires, as we like to say, to get out and to reach the food. Whatever be his consciousness, his behavior shows that he is, as an organism, *set* in that direction. This adjustment persists till the motor reaction is consummated; it is the driving force in the unremitting efforts of the animal to attain the desired end. His reactions are, therefore, the joint result of the adjustment and of stimuli from various features of the cage. Each single reaction tends to become associated with the adjustment. But the unsuccessful reactions are less strongly associated than the successful, because each one of the former is at some moment given up or inhibited; and this inhibition, too, being made under the influence of adjustment, tends to become associated with it and so to interfere with the association between the adjustment and the performance of this particular reaction. In the case of the

successful reaction, however, the phase of inhibition does not occur, and the only association with the adjustment is of the positive sort. Thus the successful reactions must, in the long run, gain an advantage over the unsuccessful reactions.

"The preceding explanation, although satisfactory as far as it goes, is not fully adequate to account for all the facts. In particular, it does not take full account of the pleasure accompanying success, and of the often strong displeasure that attends baffled effort. Such pleasure and displeasure certainly occur in human learning, and seem present in the higher animals. Exactly how these emotions act to strengthen one association and to weaken or counteract another cannot readily be seen; but it is safe to assume that they correspond to some genuine dynamic process of great efficacy. The displeasure of failure and baffled effort, in particular, must be the indication of a stronger inhibitory process than is provided for in the preceding explanation" ['11, pp. 551f.].

"There can be no manner of doubt that an unsuccessful reaction acts as a punishment and leads to avoidance of that particular act; and it is also highly probable that that one of the preparatory reactions which leads over directly into the consummatory reaction gets the benefit of the dammed-up energy tending towards the consummatory reaction, and so becomes integrated with the consummatory reaction into a single complex act. If this is a correct interpretation, we have in this instance of learning something that we have missed hitherto, namely, the addition, not only of new connections between stimulus and native response, but the building up of two natural responses into a single complex act. The cat does not simply eliminate unsuccessful reactions to the situation, and thus leave the successful response as the sole reaction, but it learns the complex response of pushing-the-bolt-going-out-and-eating" ['18, p. 91].

"Besides this, the 'law of effect' must also be taken into

account. When one of two possible reactions to a given stimulus has in the past led to punishment, that response is placed at a disadvantage as compared with the other which has not been punished. When the reaction to a stimulus, however frequently made in the past, has given way to a condition of negative adaptation, that stimulus is placed in a position of disadvantage as compared with a stimulus to which adaptation has not occurred. When reaction to one feature of a situation has resulted in a check or failure, that stimulus is placed in a position of disadvantage; and when reaction to a particular feature has brought success and satisfaction, that reaction has the advantage over all others that are capable of being aroused by the given situation. Thus the advantage of one possible reaction over another, due to the present strength of the connection between situation and response is determined in a very complex way by the original nature and past history of the individual" ['18, p. 117].

"Can it [the strengthening of the connection that brings 'success'] be explained as an instance of the sub-law of intensity? An animal, or man, who sees success coming as he is making the reaction that leads directly to success, throws himself unreservedly into this reaction, in contrast with his somewhat hesitant and exploratory behavior up to that time. The dammed-up energy of the reaction-tendency finds a complete outlet into the successful reaction, and therefore the successful reaction is more intensely exercised than the unsuccessful. This seems like a pretty good explanation, though perhaps not a complete explanation." ['21, p. 393.]

This explanation may have a certain validity for cases where the learner "sees success coming as he is making the reaction that leads directly to success," but such cases are relatively few. Only the final dash into the food compartment would be strengthened in this way in the case of rats in mazes. Only a small late fraction of the button-turning, or loop-pulling of dogs and cats in puzzle boxes would be

connected with confinement in the puzzle box. Little if anything useful would occur in learning to typewrite or play the piano by a strengthening of the connection between various situations and whatever came just as one saw the letter appear on the sheet or heard the chord. In almost all multiple-choice experiments the animal does not see success until after the crucial response is completed. In the experiments of Chapters IX and X, the learner usually does not "see success" until he hears the experimenter's announcement of *Right*. The strengthening of the connection between a situation and small late fractions of the useful response to it seems likely to do more harm than good.

It is the connection between the situation and the "right" or useful response as a whole that is needed for adaptive learning. The "sight of success coming" does strengthen that connection as a whole not so much by intensifying a late fraction of it, as by rewarding the early fraction of it. The satisfying sight of success coming strengthens the connection whose after-effect it is and leads the animal not only then and there to complete the useful response, but in recurrences of the problem-situation to be more likely to initiate it. The "sight of success coming" acts not only as an intensifier of what follows it, but also as a satisfier of what precedes and produces it.

In a still more recent discussion of the same matter Woodworth falls back upon freedom from inhibition ['29, pp. 170-175].

§ 6. Doctrines of indirect action by way of representations

Lloyd Morgan ['95], Hobhouse ['01, pp. 890ff.], Tolman ['28], H. L. Hollingworth ['28, pp. 217ff.] and others, while accepting the fact that the after-effects of connections modify them, attribute the fact to a change in the situation, to wit, the addition of some revival or representation of the

after-effect. I quote recent statements from Tolman and H. L. Hollingworth.

"(2) All learning may be said to involve the representation of the ends of acts at moments before their actual occurrence.

"(3) When these represented ends of acts are situations which when actually present lead at once (given the animal's innate and acquired endowment) to further appropriate responses, then the propensities towards the acts leading to those ends will become strengthened.

"(4) When, on the other hand, these represented ends of acts are situations which when actually present lead only to negative or avoidance responses, then the propensities towards the acts leading to those ends will become weakened." [Tolman, '28, p. 51.]

"Even the lower animals are trained by punishing or rewarding them for their bad and good acts, respectively. Can this practice, with its undoubted practical warrants, be justified and explained without assuming that pleasantness and unpleasantness, or their physiological correlates, work *backward* by way of 'stamping in' or 'stamping out' the movements which produced them or were followed by them? . . .

"There is a very ready answer, and it is astonishing how commonly it is overlooked. Pleasantness and unpleasantness, reward and punishment, do affect conduct. They do so, however, by modifying the *stimulus*, not by mystical operations on the movements. The burnt child shuns the fire, not because pain did anything to his movements, but because, since that pain, the stimulus has changed. It is no longer 'flame plus curiosity'; it is now 'flame plus fear.'

"For the present stimulus is not merely the flame, which may be, for the fireman, an abstract and isolated object. The present stimulus is the total situation of the moment, the complete antecedent of present behavior. This includes

the seen flame, plus the imaged pain, plus the fearful emotion redintegrated by the flame on the basis of the previous context. The 'avoiding reactions' are not merely to the flame but to this total situation. Once the stimulus was visual pattern, plus interest; now it is visual pattern, plus imaged pain pattern, plus emotional tone of strong fear." [H. L. Hollingworth, '28, pp. 218f.]

The same external situation recurring often does evoke in its later appearances memories or images of previous responses and of the punishments which previously followed certain responses to it. In learning when one more or less deliberately chooses what response one shall make, such representations may play a large rôle. But the facts of Chapters IX and X prove that the after-effects of a connection may influence it directly, without mediation by any representation of pain or reward of the response producing either. In much learning of skilled acts there is no time for such to intervene.* Also it seems unlikely that an imaged pain or reward should have power to strengthen a connection if the real pain or reward had none.

§ 7. Summary of sections 3 to 6

On the whole, the alleged evidence against the potency of after-effects turns out to be rather in its favor; and the arguments against its direct potency and in favor of indirect potency *via* later representations of it not only fail to fit the facts of learning but also are subject to all the difficulties of direct action. The substitutes suggested to do the work which satisfiers and annoyers seem to do form a motley array of frequency, recency, intensity, finality, congruity, freedom from inhibition, and harmony with the dominant or principal activity, suggestive rather of occasional features of learning than of its fundamental causation.

The substitutes for the direct action of the after-effects of a connection upon it seem to have been found or devised

* Snoddy ['20] took special pains to discover the part played by images of the movements in learning a motor performance (mirror-tracing of a path) and found it to be practically nil ['20, pp. 40-45].

more because they were free from certain supposed difficulties of such direct action than because of intrinsic merit as explanations of the selection of one response in preference to others for connection with a situation. Psychologists have been so afraid that assigning power to satisfyingness as a cause of learning might entail interaction or hedonism or mysticism or an unknown physiological analogue of the hedonic consciousness, and so afraid that direct action of a consequence of a connection might entail impossible time relations, that they have strained frequency and recency and intensity incredibly and, when these are found wanting, have clutched at any straw of congruity or dominance or freedom from inhibition or principal response or representations of after-effects.

We have suggested elsewhere (in Chapter X) that there is no more difficulty in crediting satisfying states of affairs with power to strengthen the connections which they shortly follow and to which they belong than in crediting them with power to modify behavior at all. A child puts a novel object, to wit, a brown square of sweet chocolate, into his mouth and sucks at it. If the resulting sweet taste makes him then and there more likely to put a second such object into his mouth than a resulting bitter taste would, why will it not make him more likely to put a third such object into his mouth a minute or an hour or a day later?

We have also suggested that the physiological equivalent of the connection does not vanish and become inaccessible instanter but remains long enough to be acted upon by whatever follows it and "belongs" with it. In the illustration just used, the resulting sweet taste not only makes the child more likely to continue sucking and less likely to spit out the object than a bitter taste would, but also more likely then and there to put a second object of the same sort into his mouth. The action of the satisfier works upon something left by and corresponding to the connection *see such and such an object* $\longrightarrow$ *put it in the mouth.* The physiology of this may be mysterious, but the fact seems sure. Noth-

ing is gained by making the action indirect and supposing that an image or other representation of the sweet taste does the work. The representation does, it is true, come ahead of the *second* operation of the connection, but that is really irrelevant. In order that the second sight of the chocolate may be more likely to produce the response than the first was, there must have been action upon something left by the first. The progress shown by the second must all have been made *before the second begins*.

We have two real difficulties. One is to understand how there can be states of affairs which an animal does nothing to avoid, often doing such things as attain and preserve them, and other states of affairs which an animal often rejects or avoids or changes so far as his repertory of behavior permits. The other is to understand how a connection can be strengthened by any force. Imaginary difficulties should not be added. The Law of Effect in learning demands nothing more from satisfiers than their existence, and nothing more from connections than that they leave some trace which is then and there modifiable so as to increase the probability of the action of the connection in question in the future.

APPENDIX I

Experiments in responding to a length by an estimate of its magnitude

Experiments 2, 3, and 4 are like Experiment 1, but with certain improvements.

Experiment 2

Experiment 2 was conducted with three subjects, Br, S, and Wo. The same lengths and the same procedure were used, but no one of the subjects knew the constitution of the series. Br estimated each of the twenty-five lengths 120 times; S, 210 times; Wo, 240 times. The status of each subject in the first thirty estimates of each length was such as to make it certain that the connections involved were modifiable, and also improvable, in the sense that closer approximation to the truth could be attained than was attained in the first thirty.*

The results are shown in Tables 3, 4, and 5. We have studied these in many ways trying to reconcile them with the doctrine that the strong connections gain at the expense of the weak, but without success. If we use the most obvious and most reasonable treatment, of comparing the first thirty with the last thirty for each subject for each length, we find two outstanding facts.

The response which was most frequent in the first thirty showed, in the last thirty, a gain in only twenty-five of the seventy-five cases, remaining unchanged in six and losing in forty-four. The connections did not, however, remain *in statu quo*. In the first place, the medians shifted down for Br, and up for S. In the second place, although the most frequent did not gain at the expense of the least frequent, there was a change toward stereotypism or reduced variability in the response. The variability of

* All three subjects had considerable constant errors which training where the law of effect is permitted to operate freely can eliminate, and larger variable errors than persons of their general ability need to retain. Br, S, and Wo, after Experiments 1 and 2 were finished, were trained with opportunity for the law of effect to operate and did reduce their errors.

the estimates of any one length around the subject's own median estimate of it for the thirty in question, decreased in fifty-eight cases, was the same in one case, and increased in only sixteen cases. These facts are shown in Tables 6, 7, and 8.

Experiment 3

Experiment 3 was similar to Experiment 2, save that the series extended from $4\frac{1}{2}''$ to $8\frac{3}{4}''$, with five samples of 42, 43, 82, and 83, ten samples of 5, 51, 8, and 81, fifteen samples of 52 and 73, and twenty samples of each of the lengths from 53 to 72 inclusive. Subjects H and To estimated the length of this series eight times. We do not present tables for them comparable to Tables 3, 4, and 5, but only tables comparable to Tables 6, 7, and 8. These tables (9 and 10) show the most frequent early response losing with the progress of the experiment, the *status quo* being changed by a shifting of the central tendency and a reduction in the variable error. The median estimate shifts upward for H and downward for To.

Experiment 4

Experiment 4 was similar to Experiment 2. Subject D completed seventy estimates of each length. Table 11 presents the facts concerning the shift of the means, the frequency in the last thirty of the response most frequent in the first thirty, and the change in the variability.

It may seem strange that the variability should decrease although the most frequent response in the early stages does not gain, but loses. If the distribution of the responses were unimodal and symmetrical and the central tendency stable, a reduction in the variability would usually involve the increase of the most frequent. In the case of the estimates of these lengths, the distribution at any stage may be nearly of the "normal" type, but the central tendency is almost never stable in the early stages. What often happens is that (1) in the first ten judgments of each length there are some extremely wide variations, that (2) from the beginning well on into the experiment there is a gradual shifting of all the estimates up, or down, or up and down, that (3) certain tendencies are preserved for relative stability in the latter part of the experiment, but that (4) early frequency has no demonstrable potency in the selection of the tendencies to be so preserved. If

early frequency were potent it should prevent the shifting of the central tendency, especially such reverse shifts as were shown by S and T.

If we modify our use of the *status quo* to make it mean the total of the tendencies to response shown in the first half of the series (from 30 responses for D to 120 for Wo) and modify our use of the "most frequent response" to make it mean the group of estimates of successive amounts occurring in about 75 percent of the first half of the series, the general tendency is to maintain these responses at about the same frequency in the last half of the series, and to reduce the variability in one way or another to about four-fifths of what it was. A summary of the facts by this analysis is given in Table 12.

On the whole, these experiments indicate then that the tendencies to respond to a situation of the sort presented do not constitute a fixed status, but an inconstant, susceptible, fluid condition; that under continued repetition of the stimulus the condition becomes less variable, tending toward stereotypism of a sort; but that there is no evidence that the more frequent, merely by being more frequent, gain at the expense of the less frequent.

TABLE 3

DISTRIBUTION OF RESPONSES OF BR TO LENGTHS 5″ TO 11″, BY SUCCESSIVE 30'S

Sit.	Res.	Frequencies in 1 to 30	31 to 60	61 to 90	91 to 120
5	5	12	12	4	12
	51	10	4	3	10
	52	2	10	15	6
	53	5	1	1	1
	6	1	2	7	1
	61		1		
51	5	2	3	3	2
	51	6	3	3	1
	52	10	9	4	13
	53	7	3	1	6
	6	1	8	11	7
	61	1	3	3	1
	62	3	1	5	
52	5	1			
	51	2			1
	52	6	4	3	5
	53	2	1	1	6
	6	8	8	12	13
	61	5	4	7	4
	62	3	11	5	
	63	3	1	1	1
	7		1	1	
53	52	3	1	2	2
	53	4		2	3
	6	7	10	3	11
	61	10	7	8	3
	62	6	9	12	8
	63		1	2	2
	7		2	1	1
6	6	5	1		5
	61	7	1	4	4
	62	8	13	9	13
	63	8	8	13	7
	7	1	5	4	1
	71	1	2		
61	53		1		
	6	1	1	1	1
	61	3			8
	62	8	8	4	8
	63	6	3	9	9
	7	4	16	11	4
	71	5	1	3	
	72	2		2	
	73				
	8	1			
62	61				3
	62	1	3	4	8
	63	9	5	3	3
	7	6	9	14	12
	71	10	7	4	2
	72		5	5	1
	73	2	1		1
	8	1			
	81				
	82	1			
63	61		1		2
	62	3	1		2
	63	6	5		6
	7	11	9	12	10
	71	2	5	7	5
	72	4	7	10	5
	73	3	2	1	
	8				
	81	1			
7	62		2		2
	63	3	3		3
	7	9	8	6	9
	71	4	4	4	8
	72	9	8	12	6
	73	4	3	4	2
	8		2	3	
	81	1		1	
71	62				1
	63		1		2
	7	2	4	3	7
	71	7	5	2	8
	72	8	10	10	5
	73	5	5	10	7
	8	4	5	5	
	81	2			
	82	2			
72	63	1	1		1
	7	2	3	2	4
	71		2	2	9
	72	7	7	7	7
	73	6	10	10	5
	8	10	7	8	4
	81	1		1	
	82	2			
	83				
	9	1			
73	7	2	1		2
	71		1		8
	72	4	4	2	4
	73	5	5	9	6
	8	11	19	15	10
	81	6		4	
	82				
	83				
	9	2			
8	71	2		1	2
	72	3	2	2	4
	73	3	5	6	4
	8	11	17	11	16
	81	4	5	10	4
	82	2	1		
	83	1			
	9	1			
	91	1			
	92				
	93	2			
81	7				1
	71	1			
	72		3		4
	73	1	1	3	2
	8	5	13	11	12
	81	7	11	11	10
	82	5	2	5	1
	83	4			
	9	1			
	91	3			
	92	1			
	93	1			
	10				
	101				
	102	1			
82	72				1
	73				2
	8	3	9	11	8
	81	8	13	11	11
	82	6	6	7	8
	83	2	2	1	
	9	3			
	91	3			
	92	1			
	93	2			
	10	1			
	101				
	102	1			
83	8	2	7	3	7
	81	6	4	11	12
	82	6	15	13	9
	83	2	4	3	1
	9	1			1
	91	3			
	92	5			
	93	3			
	10	1			
	101				
	102				
	103	1			
9	8		2	1	4
	81		2	9	10
	82	11	16	11	10
	83	1	5	3	4
	9	3	3	5	2
	91	2	1	1	
	92	4			
	93	5			
	10	1	1		
	101	1			
	102				
	103	1			
	11	1			
91	8				1
	81	4		1	6
	82	1	6	10	8
	83	3	8	4	7
	9	4	13	4	6
	91	2		1	2
	92		2	1	
	93	2			
	10	5	1	2	
	101	1		1	
	102	7			
	103				
	11				
	111				
	112	1			

TABLE 3 (*Continued*)

Distribution of responses of BR to lengths 5″ to 11″, by successive 30's

Sit.	Res.	Frequencies in 1 to 30	31 to 60	61 to 90	91 to 120
92	8				1
	81		2		2
	82	1	5	3	5
	83	3	4	11	3
	9	4	7	7	13
	91	1	3	2	3
	92	5	4	2	2
	93	1	1	1	
	10	4	2		1
	101	2	1	1	
	102	5	1	3	
	103	2			
	11	1			
	111	1			
93	81				1
	82	1		2	2
	83		3	4	6
	9	5	6	6	6
	91		6	3	5
	92	1	6	5	6
	93	1	1	2	1
	10	2	6	4	2
	101	3	1	1	1
	102	7	3		
	103	2	1		
	11	4			
	111	1			
	112	1			
	113	1			
	12	1			
10	82		1		
	83		2		5
	9	1	4	5	8
	91		2	5	7
	92	1	2	4	4
	93	1	4	2	1
	10	2	9	6	5
	101	2	4	2	
	102	2	1	3	
	103	5	1	3	
	11	6			
	111	3			
	112	4			
	113	2			
	12	1			
101	83				1
	9		1	4	3
	91		1	1	4
	92	2	2	2	2
	93	1	1		5
	10	1	6	4	7
	101	3	2	3	2
	102	5	8	8	6
	103	3	3	2	
	11	4	6	6	
	111	2			
	112	3			
	113	1			
	12	2			
	121	3			
102	9		1	2	
	91			1	
	92	1		2	1
	93		1		1
	10	2	4		6
	101		1	1	6
	102	2	4	2	8
	103	4	3	3	6
	11	7	11	12	2
	111	6	1		
	112	6	4	5	
	113				
	12			2	
	121				
	122	1			
	123	1			
103	9		1		
	91	4			
	92		1	1	2
	93			1	1
	10		1	2	2
	101		1		1
	102	1	7	5	9
	103	2	1	3	3
	11	7	8	10	9
	111	7	3	5	1
	112	4	4	2	1
	113		1		
	12	2	2	1	1
	121	1			
	122	4			
	123				
	13				
	131	1			
11	93				1
	10	1			2
	101		2	1	
	102		2	2	4
	103	1	3	2	3
	11	4	7	12	12
	111	2	5	5	3
	112	5	5	6	5
	113	4	1		
	12	6	3	2	
	121	2	1		
	122	3	1		
	123	1			
	13	1			

TABLE 4

DISTRIBUTION OF RESPONSES OF SP TO LINES 5″ TO 11″, BY SUCCESSIVE 30'S

Sit.	Res.	Frequencies in 1 to 30	31 to 60	61 to 90	91 to 120	121 to 150	151 to 180	181 to 210
5	4					4	3	
	41	7	6	2	2	4	13	6
	42	12	9	11	4	17	10	13
	43	9	10	12	9	4	4	11
	5	2	5	4	8	1		
	51			1	6			
	52				1			
51	4	1						
	41	2				3	6	
	42	5	2	8	2	10	12	7
	43	11	6	13	5	17	11	13
	5	9	11	5	5		1	8
	51	1	8	3	8			1
	52	1	3	1	7			1
	53				3			
52	41					1		
	42	2	2			2	7	1
	43	6	1	1	1	19	14	3
	5	9	11	11	6	5	6	11
	51	8	8	9	3	1	3	10
	52	4	7	7	13	1		3
	53	1	1	2	6	1		2
	6				1			
53	41					1	1	
	42		1				2	
	43	2			1	7	10	1
	5	8	1	2	2	13	13	5
	51	10	6	6	2	5	4	11
	52	8	10	12	8	3		6
	53	2	10	8	9	1		5
	6		2	2	5			2
	61				3			
	42	1						
	43	2				1	2	
	5	2		3		6	13	
	51	9	4		3	7	5	4
	52	8	11	13	6	6	5	6
	53	6	8	5	7	8	5	15
	6	1	4	6	7	2		4
	61	1	1	3	5			1
	62		2		2			
	63							
61	43						1	
	5	1				6	5	1
	51	2			1	3	7	
	52	4		2		8	10	5
	53	12	5	7	5	10	7	11
	6	6	9	9	1	2		7
	61	3	10	8	2			5
	62	2	5	4	12	1		1
	63		1		9			

Sit.	Res.	Frequencies in 1 to 30	31 to 60	61 to 90	91 to 120	121 to 150	151 to 180	181 to 210
62	5						2	
	51	1				1	6	1
	52	2				4	4	4
	53	5	1			9	10	2
	6	10	8	4	2	9	7	10
	61	6	7	7	4	5	1	5
	62	4	11	12	14	1		8
	63	1	3	5	9	1		
	7	1		1				
	71			1	1			
63	51						1	
	52	1				1	5	
	53	3				10	11	
	6	6				6	9	3
	61	8	5	1		8	4	12
	62	9	11	8	5	3		14
	63	2	10	8	7	2		1
	7	1	2	5	8			
	71		1	5	3			
	72			2	5			
	73		1	1	2			
7	52						1	
	53					1	5	
	6	6				8	9	1
	61	7	3			9	12	4
	62	8	3	4	1	9	3	18
	63	6	14	8	3	3		5
	7	3	2	5	4			1
	71		6	9	9			1
	72		2	3	9			
	73			1	4			
71	53						2	
	6	4	1			1	5	
	61	2	1			1	6	
	62	4	1	1		13	15	11
	63	10	8		1	6	2	8
	7	7	2	6	2	3		6
	71	1	9	6	3	3		5
	72	2	7	7	12	2		
	73		1	8	11			
	8			2	1	1		
72	52						1	
	53							
	6						1	
	61					1	5	
	62	7	1			3	14	1
	63	12	3			8	6	8
	7	7	5	1		10	2	9
	71	4	10	2	6	3	1	3
	72		6	12	8	3		7
	73		2	10	10	2		2
	8		2	5	6			
	81							
	82		1					

TABLE 4 (*Continued*)

Sit.	Res.	Frequencies in						
		1 to 30	31 to 60	61 to 90	91 to 120	121 to 150	151 to 180	181 to 210
73	61	1						
	62					2	7	
	63	7				2	11	2
	7	9	4			6	7	6
	71	6	5		1	9	2	10
	72	6	13	5	4	7	3	6
	73		8	15	10	4		6
	8	1		2	7			
	81			5	6			
	82			2	2			
	83			1				
8	61	2						
	62	1					3	
	63	5				1	5	
	7	13	2			2	7	
	71	7	12	1	2	4	3	1
	72	2	12	5	5	11	12	10
	73		4	4	8	8		11
	8			8	6	1		7
	81			9	7	2		1
	82			3	2	1		
81	62	1						
	63	1					1	
	7	3				1	4	
	71	2	1				5	1
	72	16	5			11	12	8
	73	7	12	2	1	10	7	9
	8		9	3	4	5		6
	81		3	6	7		1	5
	82			8	8	3		1
	83			9	7			
	9			1	2			
	91			1	1			
82	63	1						
	7	5						
	71	4						
	72	5	1			3	6	1
	73	9	7	1		11	16	5
	8	5	5	1		7	6	8
	81		6	3	4	3	1	7
	82		6	7	7	3		5
	83	1	4	11	10	2		4
	9		1	5	5	1	1	
	91				4			
	92			1				
	93			1				
83	71	3						
	72	7					3	
	73	10	2			2	11	1
	8	6	8			3	6	2
	81	2	6	2		4	7	6
	82	2	11	2	3	11	2	6
	83		3	6	13	9	1	8
	9			4	5	1		5
	91			2	4			2
	92			8	5			
	93			6				
	71	1						
	72	5	1				1	
	73	8	1			1	2	
	8	9	3			3	7	
	81	3	5	1		3	6	
	82	3	8	3		7	8	11
	83	1	5	4	2	6	4	7
	9		5	2	6	6	2	5
	91		2	9	9	3		4
	92			6	7	1		3
	93			3	5			
	10			2	1			
91	72	1					1	
	73	4						
	8	12	4				1	
	81	3	1			2		
	82	4	6			3	5	1
	83	6	5	2	2	8	12	5
	9		8	3	1	6	7	8
	91		4	5	6	6	3	5
	92		2	3	13	2	1	6
	93			7	6			3
	10			4	1	3		2
	101			5	1			
	102			1				
92	73	2						
	8	3						
	81	10	1					
	82	4	4			1	4	
	83	7	7			4	4	
	9	2	4	2		1	4	3
	91	1	3			7	7	3
	92	1	6	7	8	8	6	5
	93		3	3	8	4	4	12
	10		1	5	9	3	1	5
	101			5	2	2		2
	102		1	6	3			
	103			2				
	11							
	73	2						
93	8	1						
	81	2					2	
	82	5	1				1	
	83	7	1			1	2	1
	9	6	5	1		2	6	
	91	4	7	2	1	3	1	3
	92	3	4	2		3	9	7
	93		6	5	9	4	8	2
	10		4	5	12	8	1	11
	101		2	5	6	7		2
	102			5	1	1		3
	103			3	1			1
	11			2		1		

TABLE 4 (*Continued*)

Sit.	Res.	Frequencies in 1 to 30	31 to 60	61 to 90	91 to 120	121 to 150	151 to 180	181 to 210
10	81	2						
	82	4				1		
	83	6	1				1	
	9	5	1					
	91	5	6			2	4	1
	92	3	8	1		4	5	2
	93	1	7	4	1	2	6	4
	10	2	2	4	9	9	12	7
	101		2	3	9	2	2	9
	102	1	2	8	3	7		5
	103	1	1	6	6	3		1
	11			2	2			1
	111			2				
101	8	1						
	81							
	82	1						
	83	3						
	9	3	1					
	91	5				1		1
	92	4	5					
	93	4	3	1		1	6	
	10	9	7	3	5	4	10	5
	101		5	4	5	4	5	3
	102		6	5	10	7	7	2
	103		3	7	6	6	2	7
	11			4	3	6		9
	111			5	1	1		1
	112			1				2
102	81	1						
	82		1					
	83	2						
	9	5						
	91	3						
	92	1	1					
	93	5	8				1	1
	10	8	4	1	1	2	7	

Sit.	Res.	Frequencies in 1 to 30	31 to 60	61 to 90	91 to 120	121 to 150	151 to 180	181 to 210
102	101	3	4	2	3	4	3	
	102		6	4	3	3	6	8
	103	1	5	3	7	5	3	3
	11	1	1	6	7	11	7	9
	111			6	4	4	2	3
	112			7	4	1	1	5
	113			1	1			
	12							1
103	8	1						
	81							
	82							
	83	1						
	9	2						
	91	1						
	92	3	1					
	93	6	3					
	10	3	4		1	1	3	
	101	7	9			2	7	3
	102	4	5	1	3	3	7	2
	103	2	7	5	5	10	8	9
	11		1	7	10	6	3	7
	111			4	5	7	2	8
	112			9	3	1		1
	113			4	2			
	12				1			
11	93	2	1					
	10	7	1					
	101	2	3				1	
	102	7	7		3		3	
	103	8	7	1		2		2
	11	4	8	5	5	5	14	7
	111		3	5	11	3	6	4
	112			10	6	18	6	11
	113			6	4	2		3
	12			3	1			3

TABLE 5

Distribution of responses of WO to lengths 5″ to 11″, by successive 30's

Sit.	Res.	Frequencies in 1 to 30	31 to 60	61 to 90	91 to 120	121 to 150	151 to 180	181 to 210	211 to 240
5	43	4	3			1	3		
	5	17	20	27	21	26	20	12	26
	51	9	6	2	9	3	7	16	4
	52		1	1				2	
51	42					1			
	43								
	5	6	5	8	4	7	8	2	6
	51	13	20	20	18	17	12	8	12
	52	7	5	2	8	5	9	14	10
	53	1					1	6	2
	6	3							
52	43	1							
	5					1	1	1	
	51	4	10	16	2	14	1	4	4
	52	10	13	4	18	9	9	5	10
	53	7	5		7	4	18	19	16
	6	8	2		3	2	1	1	
53	51	2		3	1		1		1
	52	4	9	9	5	6	2	1	
	53	6	6	6	9	15	13	9	19
	6	15	13	12	14	7	13	19	10
	61	2	2		1	2	1	1	
	62	1							
6	52				2	1		1	
	53	3	1	2	1	7	3		4
	6	12	17	16	11	14	22	15	21
	61	11	9	10	11	6	5	13	5
	62	4	3	2	4	1		1	
	63				1	1			
61	53	1					1		
	6	4	4	7	5	2	7	7	10
	61	7	12	9	6	12	11	13	14
	62	16	13	10	14	11	9	7	6
	63	2	1	4	3	3	1	2	
	7				1	1	1	1	
	71					1			
	72								
	73				1				
62	6	2				1	2	2	1
	61	5	3	4	1	3	5	3	10
	62	12	17	13	8	15	13	11	9
	63	7	7	7	3	6	8	6	7
	7	2	2	4	8	4	2	6	3
	71			2	3	1		1	
	72	1	1		7			1	
	73								
	8								
	81	1							
63	6			1					
	61	2							
	62	2	6	6	1	6	5		7
	63	6	7	11	2	4	6	7	9
	7	11	10	6	13	6	9	13	6
	71	4	5	3	3	7	9	6	7
63	72	3	2	2	3	5	1	2	1
	73	2		1	4	2		2	
	8				3				
	81				1				
7	61	2							
	62	5			1	2			
	63	2	4	2	2	2	1	3	
	7	4	13	14	3	3	3	1	1
	71	6	5	3	3	7	8	10	11
	72	6	5	4	4	7	13	7	12
	73	4	2	4	7	9	5	9	6
	8	1	1	3	9				
	81				1				
71	61	2							
	62	2							
	63		1	1	1		1	3	
	7	3	8	4	1	1	3	1	1
	71	4	5	4	2	4	8	10	11
	72	10	1	4	1	12	13	7	12
	73	8	10	9	6	11	5	9	6
	8	1	2	7	11	2			
	81		3	1	8				
72	63	1							
	7	5		1			1		
	71	2		1	2	1	2		
	72	5	1	2		4	5	4	5
	73	8	12	6	4	14	19	23	19
	8	8	8	10	9	10	3	2	6
	81		7	10	10	1		1	
	82		2		5				
	83	1							
73	7	1	1						
	71	2				2	1	1	
	72	5						1	1
	73	9	4	1		9	15	7	15
	8	4	13	15	6	11	13	16	12
	81	8	9	11	13	8	1	5	1
	82	1	2	1	9				1
	83		1	2	1				
	9				1				
8	72		1						
	73	3	1			2	3	1	1
	8	10	2	2		10	14	2	9
	81	11	12	13	9	12	10	15	11
	82	4	11	10	13	6	3	10	4
	83	1	1	1	4			2	5
	9	1	2	4	4				
81	73	1						1	1
	8	1	1			5	5	6	4
	81	6	1	10		12	8	9	4
	82	14	10	13	9	6	13	7	14
	83	4	9	2	10	3	4	7	7
	9	4	9	4	9	4			
	91			1	2				

TABLE 5 (*Continued*)

Sit.	Res.	Frequencies in 1 to 30	31 to 60	61 to 90	91 to 120	121 to 150	151 to 180	181 to 210	211 to 240
82	8		1				1	1	1
	81	2	2	1		2	5	2	3
	82	9	3	5	2	9	12	7	5
	83	7	4	5	4	8	10	15	13
	9	9	14	19	15	6	2	5	8
	91	2	3		7	3			
	92	1	3		2	2			
83	81	1				1	1	1	1
	82	3	1	2	1	4	7	3	3
	83	6	2			8	11	9	10
	9	7	11	15	6	8	10	10	11
	91	9	14	9	12	7		7	3
	92	3	2	3	7	2	1		2
	93	1		1	4				
9	81	1				1			
	82	3						1	
	83	3				1	6	8	1
	9	5	5	7	3	9	15	9	9
	91	13	10	18	12	11	8	8	10
	92	5	12	4	13	6		3	7
	93		2	1	2	2	1	1	3
	10		1						
91	83	1						2	
	9	4	1	2		7	6	6	
	91	6	7	9	8	11	16	9	2
	92	11	11	10	7	10	6	7	17
	93	3	5	4	6	2	2	6	10
	10	4	4	3	8				1
	101	1	2	1	1				
	102			1					
92	83	1							
	9	1					2		
	91	2	1	4		3	6	3	
	92	8	4	14	2	10	13	5	4
	93	6	2	4	8	13	7	17	14
	10	4	14	5	15	3	2	5	11
	101	7	8	2	3	1			1
	102		1	1	2				
	103	1							
93	9	1							
	91				1	1	3	2	
	92	2		4	3	6	8	6	

Sit.	Res.	Frequencies in 1 to 30	31 to 60	61 to 90	91 to 120	121 to 150	151 to 180	181 to 210	211 to 240
93	93	9	2	6	1	19	13	12	2
	10	11	10	8	10	4	6	9	18
	101	4	12	5	10				9
	102	3	6	7	4			1	1
	103				1				
10	91			1					
	92			1		4	4	1	
	93	8	1	1	1	9	13	6	
	10	7	7	8	7	8	8	12	4
	101	3	5	7	6	5	4	5	11
	102	8	14	6	10	3	1	5	11
	103	3	2	3	4	1		1	4
	11	1	1	3	2				
101	92					1		1	
	93	2	1			2	4	4	
	10	3	2	2	1	10	17	3	
	101	6		5	3	10	5	9	3
	102	12	12	9	12	3	2	8	11
	103	2	6	8	4	2	1	5	13
	11	4	7	3	9		1		3
	111	1	2	3	1	2			
102	93	1					1		
	10					3	3	4	
	101			1	1	12	8	4	1
	102	6	3	11	6	11	8	8	2
	103	11	4	4	6	3	8	6	13
	11	6	12	11	9	1	2	5	10
	111	4	8	3	5			2	4
	112	2	3		3			1	
103	10	1				1			
	101	2		1		5	5	2	
	102	5	1	5	1	10	11	3	
	103	6		2	3	6	6	6	5
	11	8	9	10	13	5	3	7	11
	111	4	13	10	11	2	4	6	6
	112	4	7	2	2	1	1	6	8
11	101					1	2		
	102	3				3	1	1	1
	103	2			2	9	4	2	1
	11	5	4	8	4	6	5	2	3
	111	7	5	6	4	4	8	6	4
	112	13	21	16	20	7	10	19	21

TABLE 6

SUMMARY OF FIRST 30 AND LAST 30 OF 120 RESPONSES BY BR

Sit.	Divergence of the Median from the Correct Length (in ¼ inches) First 30	Last 30	Improvement	Frequency of the Initially Most Frequent Response (in percents)* First 30	Last 30	Change	Variability Around the Median Response (in ¼ inches) First 30	Last 30	Change
5	+ .8	+ .8	0	40	40	0	.81	.74	− .07
51	+1.3	+1.4	− .1	33	43	+10	.82	.86	+ .04
52	+2.0	+1.7	+ .3	26	43	+17	1.48	.78	− .70
53	+1.6	+1.4	+ .2	33	10	−23	.89	1.10	+ .21
6	+1.8	+1.96	− .16	26	33	+ 7	.97	.72	− .25
61	+2.0	+1.25	+ .75	26	26	0	1.33	.90	− .43
62	+2.25	+1.63	+ .62	31	7	−24	.98	1.10	+ .12
63	+1.05	+1.50	− .45	36	33	− 3	1.19	.96	− .23
7	+1.25	+ .63	+ .62	30	25	− 5	1.11	.64	− .47
71	+1.25	+ .13	+1.12	26	16	−10	1.17	1.13	− .04
72	+1.33	− .36	+ .97	33	13	−20	1.00	1.51	+ .51
73	+ .86	− .33	+ .53	36	33	− 3	.89	1.28	+ .39
8	+ .14	− .19	− .05	36	53	+17	1.03	.70	− .33
81	+ .70	− .83	− .13	23	33	+10	1.40	.66	− .74
82	+ .17	−1.15	− .98	26	36	+10	1.80	.75	−1.05
83	0	−1.83	−1.83	40	70	+30	2.29	.68	−1.61
9	+ .50	−2.40	−1.90	36	33	− 3	2.31	.75	−1.56
91	+2.00	−2 50	− .50	23	0	−23	3.12	1.01	−2.11
92	+1.50	−2.19	− .69	20	16	− 4	2.71	.99	−1.72
93	+2.79	−2 50	+ .29	23	0	−23	2.32	1.34	− .98
10	+3.67	−3.21	+ .46	36	0	−36	1.79	1 16	− .63
101	+2 50	−1.50	+1.00	26	20	− 6	2.20	1.69	− .51
102	+2 36	− .37	+1.99	23	6	−17	1.22	1.08	− .14
103	+2.00	− .50	+1.50	24	18	− 6	1.24	1.17	− .07
11	+3.00	− .08	+2.92	33	0	−33	1.59	1.00	− .59

* In Tables 6 to 11, when the most frequent initial response is determined and two responses of equal frequency are found, the procedure is to use the average of their frequencies in the later occurrences. If no response has an initial frequency of 20% or more, or if the two most frequent are very near 20%, the records of the two most frequent are combined.

TABLE 7

Summary of first 30 and last 30 of 210 responses by SP

Sit.	Divergence of the Median from the Right Response (in ¼ inches) First 30	Last 30	Improvement	Frequency of the Initially Most Frequent Response (in percents) First 30	Last 30	Change	Variability Around the Median Response (in ¼ inches) First 30	Last 30	Change
5	−1.83	−1.81	+ .02	40	43	+ 3	.62	.60	− .02
51	−1.86	−1.88	− .02	36	43	+ 7	.75	.64	− .11
52	−1.72	−1.50	+ .22	30	36	+ 6	.88	.72	− .16
53	−2.00	−1.68	+ .32	33	36	+ 3	.81	.89	+ .08
6	−2.37	−1.17	+1.20	30	13	−17	.90	.62	− .28
61	−1.83	− .68	+1.15	40	36	− 4	.77	.82	+ .05
62	−1.80	−1.70	+ .10	33	33	0	.92	1.00	+ .08
63	−1.87	−1.50	+ .37	30	46	+16	.96	.58	− .38
7	−2.25	−1.94	+ .31	26	60	+34	1.02	.42	− .60
71	−2.00	−2.00	0	33	26	− 7	.99	.95	− .04
72	−2.83	−1.83	+1.00	40	26	−14	.73	1.20	+ .47
73	−2.72	−1.80	+ .92	30	20	−10	.99	.91	− .08
8	−3.96	−1.14	+2.82	43	0	−43	.66	.71	+ .05
81	−3.00	−1.83	+1.17	53	26	−27	.47	.97	+ .50
82	−3.50	−1.29	+2.21	30	16	−14	1.23	1.11	− .12
83	−4.00	−3.33	+ .67	33	3	−30	.89	.97	+ .08
9	−4.39	− .93	+3.46	30	0	−30	.88	1.11	+ .23
91	−4.67	− .30	+4.37	40	0	−40	1.21	1.20	− .01
92	−4.50	+ .83	+3.67	33	0	−33	1.12	.83	− .29
93	−3.79	+ .68	+3.11	23	3	−20	1.21	1.18	− .03
10	−3.90	+ .61	+3.29	36	0	−36	1.46	.94	− .52
101	−3.00	+2.07	+ .93	30	16	−14	1.67	1.50	− .17
102	−2.90	+1.83	+1.07	26	0	−26	1.89	1.34	− .55
103	−3.17	+ .64	+2.53	23	10	−13	1.48	.95	− .53
11	−1.93	+1.68	+ .25	26	6	−20	1.39	1.04	− .35

TABLE 8

Summary of first 30 and last 30 of 240 responses by WO

Sit.	Divergence of the Median from the Correct Length (in ¼ inches) First 30	Last 30	Improvement	Frequency of the Initially Most Frequent Response (in percents) First 30	Last 30	Change	Variability Around the Median Response (in ¼ inches) First 30	Last 30	Change
5	+ .15	+ .27	− .12	57	87	+30	.48	.29	− .19
51	+ .19	+ .25	− .06	43	40	−03	.69	.60	− .09
52	+ .50	+ .56	− .06	33	33	0	.91	.59	− .32
53	+ .70	+ .24	+ .46	50	33	−17	.73	.46	− .27
6	+ .50	+ .02	+ .48	40	50	+10	.65	.33	− .32
61	+ .69	− .14	+ .55	53	20	−33	.65	.52	− .13
62	+ .17	− .06	+ .11	40	30	−10	.73	.85	+ .12
63	+ .95	+ .38	+ .57	36	20	−16	.90	.76	− .14
7	+ .83	+1.75	− .92	40	76	+36	1.67	.64	−1.03
71	+ .90	+ .75	+ .15	33	40	+07	1.03	.64	− .39
72	+ .75	+ .02	+ .73	26	41	+15	1.21	.39	− .82
73	+ .28	+ .43	− .15	30	50	+20	1.12	.55	− .57
8	+ .68	+ .95	− .27	36	36	0	.71	.83	+ .12
81	+1.00	+ .93	+ .07	47	47	0	.60	.67	+ .07
82	+1.07	+ .96	+ .11	30	27	−03	.94	.68	− .26
83	+1.21	+ .59	+ .62	30	10	−20	1.01	.71	− .30
9	+ .73	+1.00	− .27	43	33	−10	.85	.82	− .03
91	+ .86	+1.26	− .40	37	57	+20	.87	.51	− .36
92	+1.00	+1.28	− .28	27	13	−14	1.27	.58	− .69
93	+ .77	+1.22	− .45	37	60	+23	.73	.49	− .24
10	+ .50	+1.50	−1.00	27	37	+10	1.31	.68	− .63
101	+1.17	+1.58	− .41	40	37	−03	.77	.62	− .15
102	+1.23	+ .42	+ .81	37	43	+ 6	.65	.65	0
103	+ .63	+1.41	− .78	27	37	+00	1.11	.92	− .19
11	+1.79	+2.31	− .52	43	70	+27	.90	.51	+ .39

TABLE 9

SUMMARY OF THE FIRST AND THE LAST QUARTER OF THE RESPONSES BY H

	Number of Responses in			Divergence of the Median from the Correct Length (in ¼ inches)			Frequency of the Initially Most Frequent Response (in percents)			Variability Around the Median Response (in ¼ inches)		
Sit.	First Quarter	Inter.	Last Quarter	First Quarter	Last Quarter	Improvement	First Quarter	Last Quarter	Change	First Quarter	Last Quarter	Change
42	10	20	10	−2 00	+1.00	+1.00	100	00	−100	.50	1 00	+ .50
43	10	20	10	−1 00	+1 30	− 30	40	50	+ 10	1.81	.60	−1.21
5	20	40	20	− .33	+1 79	−1.46	60	15	− 45	99	.57	− .42
51	20	40	20	−1.00	+1 06	− .06	60	00	− 60	42	.31	− 11
52	30	60	30	− 43	+1 03	− .60	43	30	− 13	1 11	1 11	00
53	40	80	40	− 87	+ 93	− 06	28	09	− 19	.99	.33	− .66
6	40	80	40	− 94	+ .37	+ .57	38	58	+ 20	93	1.36	+ .43
61	40	80	40	−1.17	+ .95	+ .22	52	10	− 42	.62	.55	− 07
62	40	80	40	−1 37	+ .93	+ 44	35	00	− 35	94	.73	− .21
63	40	80	40	−2.79	+ .95	+1.84	30	00	− 30	1.97	.42	−1.55
7	40	80	40	−1.30	− .50	+ 80	37	30	− 07	87	81	− .06
71	40	80	40	−1.18	+1 04	+ 14	62	52	− 10	.64	.38	− 26
72	40	80	40	−1 83	+ .57	+1 26	37	00	− 37	.86	.66	− 20
73	30	60	30	−1.25	+ .36	+ 89	53	10	− 43	1.04	.61	− .43
8	20	40	20	−1 83	+ .07	+1.76	60	00	− 60	50	36	− .14
81	20	40	20	−1.90	− .23	+1 67	50	00	− 50	.53	51	− .02
82	10	20	10	−2 07	− .67	+1.40	70	00	− 70	.36	.48	+ .12
83	10	20	10	−1.50	−1.06	+ 44	50	90	+ 40	1.00	.28	− .72

TABLE 10

SUMMARY OF THE FIRST AND THE LAST QUARTER OF THE RESPONSES BY TO: THE NUMBER OF RESPONSES WAS THE SAME AS FOR H IN TABLE 9

	Divergence of the Median from the Correct Length (in ¼ inches)			Frequency of the Initially Most Frequent Response (in percents)			Variability Around the Median Response (in ¼ inches)		
Sit.	First Quarter	Last Quarter	Improvement	First Quarter	Last Quarter	Change	First Quarter	Last Quarter	Change
42	− .79	−1.50	− .71	70	40	−30	.45	.56	+.11
43	−1.00	−1.21	− .21	60	70	+10	.42	.45	+.03
5	− .75	−1.03	− .28	40	75	+35	.94	.33	−.61
51	−1.00	−1.33	− .33	50	60	+10	.50	.50	.00
52	− .95	−1.64	− .69	30	35	+ 5	.86	.73	−.13
53	− .40	−1.17	− .77	28	27	− 1	.96	.73	−.23
6	− .72	−1.33	− .61	45	57	+12	.66	.53	−.13
61	− .30	−2.03	−1.73	37	02	−35	.72	.33	−.39
62	+ .07	−1.93	−1.86	27	10	−17	1.09	36	−.73
63	+ .50	−1.50	−1.00	27	14	−13	.91	.93	+.02
7	+ .33	−1.17	− .84	31	12	−19	1.17	.59	−.58
71	+1.13	+1.56	− .43	35	00	−35	1.11	.63	−.48
72	+ .91	−1.37	− .46	42	07	−35	.65	.67	+.02
73	+ .70	−1.50	− .80	33	00	−33	.78	1.21	+.43
8	+ .83	− .50	+ .33	45	05	−40	.64	.59	−.05
81	+ .64	− .94	− .30	35	05	−30	.83	.61	−.22
82	+ .90	− .50	+ .40	50	00	−50	.72	.83	+.11
83	− .17	−1.00	− .83	60	00	−60	.41	.25	−.19

TABLE 11

Summary of first 30 and last 30 of 70 responses by D

Sit.	Divergence of the Median from the Correct Length (in ¼ inches) First 30	Last 30	Improvement	Frequency of the Initially Most Frequent Response (in percents) First 30	Last 30	Change	Variability Around the Median Response (in ¼ inches) First 30	Last 30	Change
5	−1.93	−3.50	−1.57	30	03	−27	1.12	1.14	+.02
51	− .60	− .80	− .20	33	33	0	1 29	1.23	−.06
52	+ .64	+ .50	+ .14	30	13	−17	1.26	95	− 31
53	+ 59	+ .68	− .09	37	37	0	.84	.84	0
6	+ .83	+1.71	− .88	37	27	−10	1.32	.95	−.37
61	+1.64	+2.90	−1.26	27	20	− 7	1.06	.81	−.25
62	+1 70	+2.03	− .33	33	57	+24	.95	.48	−.47
63	+1.50	+1.64	− .14	43	40	− 3	.87	.76	−.11
7	+1 30	+1.50	− .20	30	23	− 7	1.15	1.06	−.09
71	+1.79	+2.39	− .60	23	25	+ 2	1 01	.70	−.31
72	+1.73	+2.38	− .65	43	57	+14	.76	.36	−.40
73	+1 23	+1.89	− .66	50	27	−23	.78	.34	−.44
8	+ .73	+1.44	− .71	43	53	+10	.53	.39	−.14
81	+ .60	+1.19	− .59	33	33	0	.87	.73	−.14
82	+ .33	+1.17	− 84	40	30	−10	.92	.76	−.16
83	+ .60	+1.12	− .52	37	07	−30	1.09	.76	−.33
9	+1.50	+1.94	− .44	33	53	+20	1.34	.62	−.72
91	+1.25	+1.36	− .11	33	17	−16	1.48	.62	−.86
92	+1.79	+1.92	− .13	23	40	+17	1.74	.76	−.98
93	+2.79	+1.50	+1.29	30	40	+10	1.46	1.04	−.42
10	+2.83	+1.93	+ .90	23	06	−17	1 85	1.01	−.84
101	+3.75	+2.30	+1.45	30	03	−27	1.32	1.01	−.31
102	+3 50	+1.94	+1.56	26	16	−10	1.57	.70	−.87
103	+4 63	+2.63	+2.00	50	16	−34	.98	1.06	+.08
11	+3.96	+2.30	+1.66	43	26	−17	.92	.70	−.22

TABLE 12

Summary of the main changes in the responses from the first to the last halves of experiments 1 to 4

Individual	Number of Responses in Each Half	Shifts of the Median Estimate			Approach of the Median to the True Length			Gain of the Responses Most Frequent in the First Half			Using Responses Comprising Approximately 75% of the Frequencies			Change in Variability Around the Median Estimate			Median Change in Variability: as a Percent of the Initial Variability
		+	0	−	n	=	f	+	0	−	+	0	−	+	0	−	
T	60	2	21	2	1	21	3	4	1	20	4	2	19	17	0	8	+26
Br	60	1	13	11	5	14	6	11	1	13	14	3	8	6	0	19	−19
S	100	7	8	10	6	8	11	10	1	14	15	0	10	10	0	15	−14
Wo	120	2	9	14	14	9	2	4	0	21	12	0	13	8	0	17	−12
H	54*	9	9		6	11	1	8	0	10	11	0	7	4	0	14	−34
To	54*		4	14		4	14	5	0	13	6	0	12	3	0	15	−23
D	30	6	12	7	6	13	6	9	5	11	13	4	8	3	1	21	−31
Sum.		27	76	58	38	80	43	51	8	102	75	9	77	51	1	109	Med.—23

* 20, 40, 60, or 80, the average being 54.

*

*

APPENDIX II

Experiments in responding to a signal by making a movement. Experiments 6 to 22

Experiment 6

At the conclusion of Experiment 5, subject T drew with eyes closed, 3810 lines, trying to make each 2″ long. As before, there was no knowledge of results from beginning to end. From 158 to 231 were drawn at each sitting. There were nineteen sittings, spread over seven days. Although, at the end of Experiment 5, T was drawing lines with a mean of about 2″, having gradually increased the length during Experiment 5, he did not continue this mean, nor did he continue the increase. He dropped in the first sitting to a median of about 1.6″, then dropped to 1.37″ in the next four sittings, then to 1.25″ in the next three, then changed to 1.37″ in the next four, then to 1.36″ in the next four, then to 1.17″ in the last three. The distributions of the responses at each sitting are shown in Table 14.

Evidently the ability to draw a 2″ line in one quick movement with eyes closed, was, for this subject, a rather inconstant and susceptible function. But it does not seem to be susceptible to drainage toward the responses of greater frequency. Comparing the first 193 with the last 202 responses, the initially most frequent loses, (24 percent to 1 percent) the divergence from the correct length increases (—.37 to —.79), and the variability around the subject's own central tendency is reduced (.11 to .08). Combining results for the first eight and for the last eleven sittings, we have Table 15. The status of the first eight is very closely maintained in the last eleven; 1.2 and 1.3 which have a frequency of 42.5 percent in the former have a frequency of 42.4 percent in the latter.

TABLE 14

EXPERIMENT 6: DRAWING 2″ LINES WITH EYES CLOSED. DISTRIBUTION OF THE RESPONSES AT EACH SITTING: SUBJECT T

Response	Frequencies in Sittings 1 to 19																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
.8																1	3		1
.9						3	3	1								1	33	6	7
1.0		1	6		8	21	19	14	1	5	12		1		2	20	68	37	34
1.1	1	14	35	5	25	71	53	46	7	28	41	2	9	2	28	31	78	81	51
1.2	3	23	30	28	52	59	59	66	18	50	65	30	24	34	57	63	26	46	59
1.3	11	43	37	44	60	34	49	52	45	52	50	52	46	71	66	42	12	32	26
1.4	16	35	29	47	41	14	21	22	51	28	32	64	45	59	38	22	2	20	15
1.5	43	27	10	18	14	4	8	3	30	12	6	36	26	29	13	5	2	6	6
1.6	47	15	7	16	7	3	3	3	24	4	8	30	26	15	6	3		1	2
1.7	44	10	1	7	1		1		12	1	2	11	11	1		2		1	1
1.8	15	2	2	2	1				3			1	2		2			1	
1.9	10		1	2					1				3						
2.0	2								1										
2.1	1											1							
Total	193	170	158	169	209	209	216	207	193	180	216	227	193	211	212	190	224	231	202
Median	1.63	1.41	1.32	1.42	1.33	1.22	1.56	1.26	1.45	1.31	1.28	1.45	1.44	1.40	1.33	1.27	1.11	1.19	1.21
Q	.11	.12	.12	.10	.10	.12	.10	.09	.11	.09	.09	.11	.12	.08	.09	.09	.08	.10	.08

TABLE 15

EXPERIMENT 6: DISTRIBUTION OF THE RESPONSES IN DRAWING 2″ LINES: SUBJECT T

Response	Frequencies in Sittings 1 to 8 Gross	1 to 8 In %	9 to 19 Gross	9 to 19 In %
.8			5	.2
.9	7	.5	47	2.1
1.0	69	4 5	180	7.9
1.1	250	16.3	358	15.7
1.2	320	20 9	472	20.7
1.3	330	21.6	494	21.7
1.4	225	14.7	376	16.5
1.5	127	8.3	171	7.5
1.6	101	6.6	119	5.2
1.7	64	4.2	42	1.8
1.8	22	1.4	9	.4
1.9	13	.8	4	.2
2.0	2	.1	1	.05
2.1	1	.1	1	.05
Total	1531		2279	
Median	1.336		1.314	
Q	.13		.12	

Experiment 7

At the conclusion of Experiment 6, subject T performed a similar experiment, but with *Draw a line 4″ long* as the core of the situation. The results, arranged in the order of the sittings, appear as Table 16.

If we take 50, 51, 52, and 53, which have a total frequency of 106 out of the first 175, their final frequency is only 70 out of 192. If we take 51 and 52 (the sequence nearest the median with a percentage near 25) the change is from 29 percent in the first 175 to 20 percent in the last 192. The last 192 are nearer to the correct length than the first 175; they vary more around their own central tendency.

There is a certain difficulty in the interpretation of the results of Experiments 6 and 7, because T may have been at his physiological limit in respect of the variable error in drawing 2″ and 4″ lines. He was not at the limit of improvability, since he was drawing the 2″ lines far too short and the 4″ lines far too long, and this was easily remediable by training in which the effects of

TABLE 16

EXPERIMENT 7: DISTRIBUTION OF THE RESPONSES AT EACH SITTING. DRAWING LINE TO EQUAL 4″ WITH EYES CLOSED. SUBJECT T

Response	Frequencies in Sittings 1 to 12											
	1	2	3	4	5	6	7	8	9	10	11	12
3.7									1			
3.8								2				
3.9												
4.0			3						3			
4.1			4	1				1	3			2
4.2		4	8					3	6	1	2	1
4.3		3	9	1				4	5	3		4
4.4		13	12	6			3	4	12	2	4	3
4.5	3	18	18	14	2	7	3	15	14	8	7	11
4.6		20	23	23	3	7	8	13	14	8	14	11
4.7	6	20	14	22	11	14	16	25	13	9	14	21
4.8	6	22	15	18	14	27	17	16	18	15	19	26
4.9	13	17	24	24	22	28	18	21	16	10	18	30
5.0	25	20	16	24	26	21	29	25	14	24	19	20
5.1	27	10	16	12	25	32	14	15	14	22	31	22
5.2	24	11	8	12	24	21	23	25	16	18	28	16
5 3	30	8	2	11	21	13	17	8	18	18	16	12
5.4	17	4	2	8	10	10	7	8	12	12	7	7
5.5	12	1		4	13	8	7	3	10	13	4	3
5.6	7			2	4	7	4	1	4	5	2	2
5.7	3			1	4	2	5	2	6	4	3	1
5.8					1			1		2		
5.9	1				1					1	2	
6.0												
6.1									1			
6.2	1						1					
Total	175	171	174	183	181	198	172	192	200	175	190	192
Median	5.23	4.83	4.77	4.93	5.15	5.07	5.07	4.96	4.97	5.13	5.09	4.96
Q	.16	.22	.23	.22	.19	.19	.21	.24	.33	.24	.21	.20

the responses were allowed to operate. Later experiments did this for T. These later experiments did not, however, reduce his variable error appreciably below what it was in Experiments 6 and 7. The training was short, and the results from subjects in which it was carried on for a longer time suggest that T could at least learn to eliminate many of his extreme deviations.

Experiments 8 to 19

Experiments 8 to 19 were all of the same nature as Experiments 5, 6, and 7. The situation was always a certain position of the body with pencil and paper, and the command, *Draw a 2″* (or *4″* or *6″*) *line*. No line drawn was even seen by the subject until he had completed the entire series.

The subjects were:

LH, who drew 4″ lines (thirteen sittings, one a day).
HH, who drew 4″ lines (thirteen sittings, one a day).

EB, who drew 6″ lines (twelve sittings, one a day on week-days).
R, who drew 2″, 4″, and 6″ lines.
W, who drew 2″, 4″, and 6″ lines.
Wo, who drew 2″, 4″, and 6″ lines.

The subjects who drew 2″, 4″, and 6″ lines, had six sittings a day for six days, as follows:

(a) one sitting drawing 5 sheets (two columns to a sheet) of 2″ lines; (b) a rest of about 5 minutes; (c) one sitting drawing 10 sheets of 4″ lines; (d) a rest of 5 minutes; (e) one sitting drawing 10 sheets of 6″ lines; (f) a rest of an hour or more; (g) a repetition of (a), (b), (c), (d), (e).

The results appear in Tables 17 to 28. They show great instability of the central tendency with shifts and reverse shifts, with increases in length predominating. From the inspection of these records nobody would derive either the doctrine of growth of the strong at the expense of the weak, or the doctrine of the maintenance of the *status quo*. What the records seem to show is a system of connections which is alive, changing, and susceptible to subtle, unnoticed internal or external influences, in comparison to which frequency seems of very minor importance. It is too weak to prevent large and frequent shifts.

A summary comparison of the first and last sittings is given in Tables 29 and 30. The most frequent response in the first sitting never shows a gain in the last sitting, often not occurring at all therein because of the great shifts of the central tendency. The variability around the median length drawn decreases in thirteen cases and increases in five. Its median reduction is 25 percent of the initial amount. The final result of the shifts of the median is more often toward the correct length than away from it (twelve cases to six); and this is corroborated by Experiment 20.

The facts are thus in general accord with those in the case of estimating lengths, showing selection, but not in any demonstrable dependence on frequency. We have also computed the distributions for the total of the first six sittings and the total of the last six for each experiment, combining class intervals so as to give a view of the general drift of change. These facts appear in Table 30, and support the conclusions drawn above from the detailed Tables 17 to 28.

TABLE 17

EXPERIMENT 8: DRAWING 4″ LINES WITH EYES CLOSED. SUBJECT LH: DISTRIBUTION OF THE RESPONSES AT EACH SITTING

Response	Frequency in Sittings 1	2	3	4	5	6	7	8	9	10	11	12	13	1–3	4–6	8–10	11–13
1.6	1													1			
1.7																	
1.8	1													1			
1.9	7													7			
2.0	10													10			
2.1	16													16			
2.2	24		3											27			
2.3	29	1	3	2				2						33	2	2	
2.4	30		4	6	1			1			3			34	7	1	3
2.5	17	4	16	5				7	1		1			37	5	8	1
2.6	16	1	12	12			3	4	6	1	1		3	29	12	11	4
2.7	13	9	25	16	1		2	14	1	2	7	1		47	17	17	8
2.8	9	9	22	15	2		6	13	2	1	10	3	1	40	17	16	14
2.9	2	8	23	25	2	1	14	13	8	4	14	3	5	33	28	25	22
3.0	2	13	20	29	2	5	23	12	15	7	9	6	6	35	36	34	21
3.1	4	9	12	16	5	6	25	20	19	17	25	9	9	25	27	56	43
3.2	2	11	10	20	6	5	21	20	13	21	26	10	9	23	31	54	45
3.3	2	12	4	8	2	14	20	22	14	35	20	14	17	18	24	71	51
3.4	1	13	6	5	14	6	12	9	21	18	15	11	21	20	25	48	47
3.5		21	3	2	5	9	17	4	8	16	8	18	18	24	16	28	44
3.6		15	1	2	17	18	9	3	17	23	8	15	11	16	37	43	34
3.7		8	1	4	7	11	1	7	10	16	3	16	7	9	22	33	26
3.8		6	1	1	11	8	4	1	7	7	4	13	12	7	20	15	29
3.9		6	1	1	11	12	3	1	8	10	4	5	9	7	24	19	18
4.0		3	1		9	7	2	1	5	7	2	8	8	4	16	13	18
4.1					12	11	1		2	1	1	7	3		23	3	11
4.2		1			11	14				3		2	1	1	25	3	3
4.3				1	4	6				1	1	2	2		11	1	5
4.4					5	3						1	1		8		2
4.5					5	5						2	1		10		3
4.6		1			1							1	1	1	1		2
4.7					2	3									5		
4.8					1	1									2		
4.9					1										1		
5.0					2										2		
Total	186	151	168	170	139	145	163	154	157	190	162	147	145	505	454	501	454
Median	2.42	3.35	2.90	3.01	3.85	3.78	3.28	3.16	3.40	3.44	3.24	3.59	3.58	2.83	3.48	3.34	3.43
Q	.20	.29	.18	.20	.34	.34	.20	.23	.27	.21	.19	.25	.30	.32	.45	.25	.26

TABLE 18

EXPERIMENT 9: DRAWING [illegible]″ LINES WITH EYES CLOSED. SUBJECT HH: DISTRIBUTION OF THE RESPONSES AT EACH SITTING

Response	Frequency in Sittings																
	1	2	3	4	5	6	7	8	9	10	11	12	13	1–3	4–6	8–10	11–13
2.1									1							1	
2.2																	
2.3																	
2.4				2											2		
2.5																	
2.6				2											2		
2.7			3	9										3	9		
2.8	2		8	10	1									10	11		
2.9	1		13	20	1				3	1				14	21	4	
3.0	3		20	30	4		2		2	2				23	34	4	
3.1	6	2	39	29	11		1		5	3				47	40	8	
3.2	4	1	35	28	19		2		13	4		3		40	47	17	3
3.3	8	2	37	34	12	3	5	2	21	5	2	5		47	49	28	7
3.4	14	6	42	30	22	3	11	5	15	11	2	1		62	55	31	3
3.5	22	10	56	19	23	10	20	14	28	20	6	7	1	88	52	62	14
3.6	32	16	26	32	39	22	31	19	41	24	19	13	1	74	93	84	33
3.7	38	20	24	15	41	36	38	26	45	20	18	16	6	82	92	91	40
3.8	40	19	29	18	35	35	51	33	30	25	33	13	7	88	88	88	53
3.9	41	17	4	15	48	33	48	43	32	24	24	24	21	62	96	99	69
4.0	35	26	8	23	42	29	32	31	21	32	26	25	30	69	94	84	81
4.1	34	20	4	14	18	37	23	37	17	44	24	34	45	58	69	98	103
4.2	28	19	3	8	15	24	24	27	12	31	26	34	33	50	47	70	93
4.3	22	24	2	6	10	28	14	20	11	28	31	36	43	48	44	59	110
4.4	12	27		2	7	16	6	19	7	12	28	31	31	39	25	38	90
4.5	14	21		3	5	9	1	3	3	14	25	29	23	35	17	20	77
4.6	14	17		2	3	7	1	6	1	7	24	20	18	31	12	14	62
4.7	7	15			1	3	1	1	1	2	13	13	14	22	4	4	40
4.8	2	15			1	1		1		2	11	10	11	17	2	3	32
4.9	2	13				1					10	10	1	15	1		21
5.0	1	16			2					1	5	4	1	17	2	1	10
5.1		12									1	1		12			2
5.2	1	16				1					2	3	1	17	1		6
5.3		6								1			1	6		1	1
5.4		1												1			
5.5		1											1	1			1
Total	383	342	353	351	360	298	311	287	309	313	330	332	289	1078	1009	909	951
Median	3.95	4.35	3.45	3.44	3.82	4.02	3.89	4.00	3.76	4.05	4.24	4.27	4.30	3.86	3.80	3.94	4.27
Q	.26	.41	.22	.34	.22	.23	.18	.20	.21	.26	.31	.26	.20	.38	.30	.25	.25

TABLE 19

EXPERIMENT 10: DRAWING 6″ LINES WITH EYES CLOSED. SUBJECT HH: DISTRIBUTION OF RESPONSES AT EACH SITTING

Response	Frequency in Sittings 1	2	3	4	5	6	7	8	9	10	11	12	1–3	4–6	7–9	10–12
2.8	7												7			
3.0	4							4			3		4		4	3
3.2	5				4	1		16		2	37	1	5	5	16	40
3.4	8	1			21	8		35		18	43	4	9	29	35	65
3 6	9	2			42	23	3	41	11	40	59	5	11	65	55	104
3.8	15	3			36	46	11	46	28	65	43	18	18	82	85	126
4.0	19	7		4	43	60	18	49	44	53	36	49	26	107	111	138
4.2	31	10	2	13	30	31	43	39	55	27	7	65	43	74	137	99
4.4	26	10	6	30	22	25	60	18	61	17		52	42	77	139	69
4.6	43	12	21	43	24	20	63	5	36	5		35	76	87	107	40
4.8	30	6	17	41	11	3	32	3	6			10	53	55	41	10
5.0	22	6	24	48	10	3	17		4	1		6	52	61	21	7
5.2	14	11	31	40	3	1	7		3			2	56	44	10	2
5.4	2	9	24	22			4						35	22	4	
5.6	0	14	24	9									38	9		
5.8	2	13	21	15									36	15		
6.0	1	14	17	2									32	2		
6.2		30	13	3									43	3		
6.4		19	12										31			
6.6		18	9										27			
6.8		4	4										8			
7.0		6	2										8			
7.2		2	3										5			
Total	238	197	230	270	246	221	261	256	248	228	228	247	665	737	765	703
Median	4.47	5.84	5.42	4.91	3.96	4.01	4.49	3.84	4.24	3.86	3.59	4.25	5.05	4.32	4.21	3.92
Q	.38	.73	.47	.31	.38	.23	.21	.28	.22	.19	.21	.20	.67	.43	.30	.29

TABLE 20

EXPERIMENT 11: DRAWING 2″ LINES WITH EYES CLOSED. SUBJECT R: DISTRIBUTION OF RESPONSES AT EACH SITTING

Response	Frequency in Sittings 1	2	3	4	5	6	7	8	9	10	11	12	1–3	4–6	7–9	10–12
.7		1	1			2							2	2		
.8	3	4	3	1	10	2	1					1	10	13	1	1
.9	7	46	9	3	16	6	6	5	2			4	62	25	13	4
1.0	26	99	35	20	32	13	15	5	1	2	5	11	160	65	21	18
1.1	44	119	77	51	53	5	43	10	12	13	6	11	240	109	65	30
1.2	66	155	93	104	112	28	36	14	23	40	5	11	314	244	73	56
1.3	72	95	64	105	88	51	31	14	29	49	11	30	231	244	74	90
1.4	84	47	71	77	79	102	28	30	12	60	18	22	202	258	70	100
1.5	85	7	59	47	31	85	23	32	19	44	12	17	151	163	74	73
1.6	73	2	45	10	12	57	28	27	16	37	15	14	120	79	71	66
1.7	73		13	2	3	32	20	52	20	25	17	18	86	37	92	60
1.8	39	1	5	1		4	11	62	22	25	8	29	45	5	95	62
1.9	15		2		1	8	22	54	32	22	11	45	17	9	108	78
2.0	8		1				18	55	31	14	10	52	9		104	76
2.1	4		1			1	22	15	29	5	12	30	5	1	66	47
2.2	1						22	8	32		25	23	1		62	48
2.3	1						15	2	26		25	9	1		43	34
2.4						1	11		15		28	5		1	26	33
2.5							7		11		18	1			18	19
2.6							3		5		20				8	20
2.7							2		5		14	1			7	15
2.8									2		7				2	7
2.9							1		1		4				2	4
3.0											2					2
3.1											1					1
Total	601	576	479	421	437	397	365	385	345	336	274	334	1656	1255	1095	944
Median	1.50	1.21	1.33	1.33	1.30	1.49	1.60	1.81	1.95	1.51	2.23	1.90	1.32	1.37	1.79	1.76
Q	.19	.11	.17	.11	.11	.12	.39	.21	.35	.19	.41	.30	.17	.13	.31	.33

TABLE 21

EXPERIMENT 12: DRAWING 4″ LINES WITH EYES CLOSED. SUBJECT R: DISTRIBUTION OF RESPONSES AT EACH SITTING

Response	Frequency in Sittings 1	2	3	4	5	6	7	8	9	10	11	12	1–3	4–6	7–9	10–12
1.2		5											5			
1.3		18		2									18	2		
1.4		62	3	5									65	5		
1.5		94	2	11									96	11		
1.6		66	15	16	2								81	18		
1.7		73	45	13	5								118	18		
1.8		59	68	19	8				1				127	27	1	
1.9	1	29	102	29	18				1				132	47	1	
2.0	3	25	85	30	35	2	1		3		1		113	67	4	1
2.1	1	11	62	38	49	3	2		8				74	90	10	
2.2	3	10	30	48	44	10		1	4				43	102	5	
2.3	5		18	49	52	10			6				23	111	6	
2.4	15		7	29	57	7	1	3	7		2	1	22	93	11	3
2.5	17	1	6	37	42	11		5	5	1	10	7	24	90	10	18
2.6	31		2	31	24	10		9	6	4	10	4	33	65	15	18
2.7	38		1	16	14	33	4	7	7	8	10	24	39	63	18	42
2.8	53			7	7	36	2	15	5	4	29	33	53	50	22	66
2.9	60			6	2	48	5	19	5	5	29	34	60	56	29	68
3.0	70			1	2	46	5	24	12	9	33	58	70	49	41	100
3.1	57			1		33	12	27	18	12	35	55	57	34	57	102
3.2	55					20	19	32	22	20	42	44	55	20	73	106
3.3	50					19	23	37	25	19	29	29	50	19	85	77
3.4	31					12	28	30	22	23	27	17	31	12	80	67
3.5	29					2	28	27	18	32	24	10	29	2	73	66
3.6	20					8	25	30	22	24	22	3	20	8	77	49
3.7	5					4	21	25	17	18	13	1	5	4	63	32
3.8	3						18	18	22	25	11		3		58	36
3.9	3						22	9	16	35	9		3		47	44
4.0	2						9	7	11	18	9		2		27	27
4.1	1						11	2	15	16	2		1		28	18
4.2	1						13	3	9	11	3		1		25	14
4.3							8	3	10	12					21	12
4.4							8		2	4					10	4
4.5							2		6	4	1				8	5
4.6							2		6	1					8	1
4.7									2						2	
4.8							3		1						4	
4.9																
5.0							1								1	
5.1							2								2	
Total	554	453	446	388	361	314	275	333	314	305	351	320	1453	1063	922	976
Median	2.85	1.53	1.87	2.00	2.15	2.78	3.38	3.10	3.15	3.37	2.99	2.93	2.07	2.44	3.49	3 27
Q	.23	.16	.13	.25	.18	.19	.29	.28	.38	.30	.27	.16	.58	.30	.31	29

TABLE 22

EXPERIMENT 13: DRAWING 6″ LINES WITH EYES CLOSED. SUBJECT R: DISTRIBUTION OF RESPONSES AT EACH SITTING

Response	Frequency in Sittings															
	1	2	3	4	5	6	7	8	9	10	11	12	1–3	4–6	7–9	10–12
1.8		4	1										5			
2.0		12	17										29			
2.2		70	79	1									149	1		
2.4	1	93	82	15									176	15		
2.6	2	85	68	34	5								155	39		
2.8	8	73	53	69	10								134	79		
3.0	30	29	17	74	54						1	2	76	128		3
3.2	49	4	11	79	79	3				1	5	3	64	161		9
3.4	53		3	39	66	3	3			4	1	12	56	108	3	17
3.6	78	1	1	17	38	10	6	4		3	12	15	80	65	10	30
3.8	95	1		7	28	14	12	14		4	10	27	96	49	26	41
4.0	94			1	9	22	17	23		7	18	31	94	32	40	56
4.2	63				3	11	34	35	4	5	14	28	63	14	73	47
4.4	33					18	62	37	15	4	29	34	33	18	114	67
4.6	26					23	54	36	16	14	51	50	26	23	106	115
4.8	7					26	54	37	19	10	38	56	7	26	110	104
5 0	4					32	39	47	31	34	43	38	4	32	117	115
5.2	2					21	19	23	33	31	47	28	2	21	75	106
5.4						31	6	12	43	35	17	14		31	61	66
5.6						29	8	4	36	35	8	3		29	48	46
5.8						26	5	2	24	41	1	1		26	31	43
6.0						16			16	38				16	16	38
6.2						7	1		8	23				7	9	23
6.4						7			11	10				7	11	10
6.6						2			2	2				2	2	2
6 8						2			1					2	1	
7.0										1						1
Total	545	372	332	336	292	303	320	274	259	302	295	342	1249	931	853	939
Median	3.92	2.62	2.57	3.13	3.39	5.15	4.70	4.74	5.46	5.55	4.83	4.68	2.96	3.48	4.89	4.96
Q	.31	.22	.22	.23	.21	.57	.28	.37	.36	.42	.36	.42	.65	.68	.40	.46

TABLE 23

EXPERIMENT 14: DRAWING 2″ LINES WITH EYES CLOSED. SUBJECT W: DISTRIBUTION OF RESPONSES AT SUCCESSIVE PAIRS OF SITTINGS

Response	Frequency in Sittings							
	1–2	3–4	5–6	7–8	9–10	11–12	1–6	7–12
1.0		2					2	
1.1	1	1					2	
1.2	9	5					14	
1.3	16	9					25	
1.4	7	18					25	
1.5	16	19	3	1			38	1
1.6	11	18	2	3	1		31	4
1.7	10	23	3	6			36	6
1.8	5	19	5	11	1	1	29	13
1.9	4	17	6	21	5		27	26
2.0	6	12	11	21	19	5	29	45
2.1	1	6	18	30	12	11	25	53
2.2	1	2	27	49	21	7	30	77
2.3	7	6	34	51	30	14	47	95
2.4	9	4	24	33	20	15	37	68
2.5	3		16	41	41	27	19	109
2.6	5	2	19	26	40	21	26	87
2.7	6	1	18	21	29	21	25	71
2.8	1		15	9	39	18	16	66
2.9	5		19	10	35	27	24	72
3.0	4		15	1	26	29	19	56
3.1	3		12		12	13	15	25
3.2	1		13		7	22	14	29
3.3	1		8		1	14	9	15
3.4			6		1	15	6	16
3.5	1		3			4	4	4
3.6			2			8	2	8
3.7			2			9	2	9
3.8						5		5
3.9			1			5	1	5
4.0								
4.1						3		3
Total	133	164	282	334	340	294	579	968
Median	1.77	1.74	2.55	2.34	2.65	2.93	2.19	2.59
Q	.48	.21	.34	.18	.25	.35	.48	.30

TABLE 24

EXPERIMENT 15: DRAWING 4″ LINES WITH EYES CLOSED. SUBJECT W: DISTRIBUTION OF RESPONSES AT EACH SITTING

Response	Frequency in Sittings 1	2	3	4	5	6	7	8	9	10	11	12	1–3	4–6	7–9	10–12
1.6	1												1			
1.8	4												4			
2.0	5		1										6			
2.2	15			1									15	1		
2.4	11		4	5									15	5		
2.6	19		4	3									23	3		
2.8	22	1	7	5									30	5		
3.0	17	2	9	6	1			1					28	7	1	
3.2	13	6	21	11									40	11		
3.4	7	5	28	3	2						2		40	5		2
3.6		8	27	4	5		1	1			5		35	9	2	5
3.8		14	16	4	15	5	7	4	1	1	12		30	24	12	13
4.0		16	6	10	19	8	9	3	1	8	17		22	37	13	25
4.2		16	6	10	18	11	14	5	5	13	24		22	39	24	37
4.4		18	2	10	17	12	16	7	9	24	17	3	20	39	32	44
4.6		13		12	12	11	23	16	15	26	17	6	13	35	54	49
4.8		5		11	7	12	14	18	23	21	17	8	5	30	55	46
5.0		5		7	2	11	11	16	21	23	7	15	5	20	48	45
5.2		6		4	1	9	12	17	14	7		13	6	14	43	20
5.4				4	1	8	10	12	19	7	3	10		13	41	20
5.6		1		3	1	8	4	9	7	3	3	15	1	12	20	21
5.8						7	4	6	4	3	1	15		7	14	19
6.0				1		4	1	2	3	1	2	13		5	6	16
6.2								1				10			1	10
6.4										1		5				6
6.6						2						3		2		3
Total	114	116	131	114	101	108	126	118	122	138	127	116	361	323	366	381
Median	2.82	4.27	3.53	4.26	4.33	4.90	4.72	5.03	5.06	4.78	4.44	5.64	3.49	4.49	4.96	4.86
Q	.29	.36	.25	.74	.29	.49	.39	.34	.32	.30	.33	.43	.53	.44	.37	.47

TABLE 25

EXPERIMENT 16: DRAWING 6″ LINES WITH EYES CLOSED. SUBJECT W: DISTRIBUTION OF RESPONSES AT EACH SITTING

Response	Frequency in Sittings															
	1	2	3	4	5	6	7	8	9	10	11	12	1–3	4–6	7–9	10–12
3.4			1										1			
3.6	1												1			
3.8	3												3			
4 0	11	2	1										14			
4.2	12	1	1										14			
4 4	9	1	3										13			
4.6	10	4	3		2		1						17	2	1	
4.8	15	2	10	1	4						1		27	5		1
5.0	10	5	14	2	8	1				2	2		29	11		4
5.2	10	9	15	4	11			2		8	2		34	15	2	10
5.4	5	16	19	1	6	5	2		4	11	4	1	40	12	6	16
5.6	5	11	13	1	7	12	3	2	6	12	7	3	29	20	11	22
5.8	1	13	12	7	10	5	6	6	12	23	9	3	26	22	24	25
6.0	1	14	3	5	6	12	8	15	15	24	9	5	18	23	38	33
6.2		5	4	9	8	14	23	17	17	19	10	13	9	31	57	42
6.4		3	2	11	6	13	19	22	12	11	13	16	5	30	53	40
6.6			1	6	8	9	22	16	8	6	14	13	1	23	46	33
6.8			1	15	6	9	11	11	12	4	11	17	1	30	34	32
7.0			2	11	5	1	3	9	15	2	12	18	2	17	27	32
7.2			1	9		7	6	4	9		11	22	1	16	19	33
7.4				5	3	1		2	5		3	11		9	7	14
7.6				4		3					1	4		7		5
7.8				3		2			2			4		5	2	4
8.0						3						2		3		2
8.2						1						1		1		1
Total	93	86	106	94	90	98	104	106	117	122	109	133	285	282	327	364
Median	4.81	5.66	5.47	6.80	5.96	6.35	6.52	6.51	6.51	6.05	6.56	6.93	5.35	6.40	6.51	6.48
Q	.42	.33	.33	.44	.62	.42	.25	.29	.46	.27	.47	.37	.44	.51	.32	.49

TABLE 26

EXPERIMENT 17: DRAWING 2″ LINES WITH EYES CLOSED. SUBJECT WO: DISTRIBUTION OF RESPONSES AT EACH SITTING

Response	Frequency in Sittings 1	2	3	4	5	6	7	8	9	10	11	12	1–3	4–6	7–9	10–12
.4										1						1
.5					3		1	2	9	4	3	1		3	12	8
.6		1		4	19	4	5	43	71	57	22	18	1	27	119	97
.7	1	5		14	50	42	64	130	181	133	96	84	6	106	375	313
.8	3	45	7	48	103	106	180	157	141	190	178	199	55	257	478	567
.9	23	97	37	102	157	145	158	131	114	140	166	181	157	404	403	487
1.0	50	116	83	100	130	110	109	65	44	53	83	97	249	340	218	233
1.1	80	88	73	97	49	51	36	19	13	12	36	23	241	197	68	71
1.2	58	31	30	42	24	20	9	5	1	5	11	10	119	86	15	26
1.3	50	15	38	23	6	8	2	4	1	3	9	8	103	37	7	20
1.4	30	6	13	7	2	5			1		6	2	49	14	1	8
1.5	19	3	7	1			1				1		29	1	1	1
1.6	6	1								1			7			1
1.7	3										1		3			1
1.8													1			
1.9	1															
2.0																
2.1																
2.2		1											1			
Total	324	409	288	438	543	491	565	556	576	599	612	623	1021	1472	1697	1834
Median	1.29	1.05	1.14	1.05	.96	.96	.92	.86	.81	.85	.90	.90	1.12	.98	.87	.90
Q	.126	.098	.110	.110	.097	.096	.087	.097	.096	.090	.089	.083	.12	.10	.095	.086

TABLE 27

EXPERIMENT 18: DRAWING 4″ LINES WITH EYES CLOSED. SUBJECT WO: DISTRIBUTION OF RESPONSES AT EACH SITTING

Response	Frequency in Sittings 1	2	3	4	5	6	7	8	9	10	11	12	1–3	4–6	7–9	10–12
2.1	1												1			
2.2	2		1										3			
2 3	8	2		1									10	1		
2.4	6	1	5	1									12	1		
2.5	5		3	3		1							8	4		
2.6	11	2	5	2	2	1							18	5		
2.7	26	2	7	10	1	2							35	13		
2.8	21	6	10	14	6	1	1						37	21	1	
2.9	34	16	17	27	5	8	3						67	40	3	
3.0	37	30	32	62	18	11	7			3	1		99	91	7	4
3.1	28	17	29	48	23	24	8			11			74	95	8	11
3.2	24	20	44	45	19	24	20			9	3		88	88	20	12
3.3	26	26	32	49	59	22	36		4	13	4	3	84	130	40	20
3.4	18	27	38	40	70	29	43		3	19	7	3	83	139	46	29
3.5	18	23	31	26	57	39	56	1	9	29	6	4	72	122	66	39
3.6	12	39	32	27	63	57	49		8	28	14	9	83	147	57	51
3.7	13	24	27	23	57	34	51		16	48	30	7	64	114	67	85
3.8	8	24	21	15	53	40	46	2	11	33	49	24	53	108	59	106
3.9	7	23	15	8	42	30	42	8	23	43	39	26	45	80	73	108
4.0	2	21	7	8	27	23	31	12	33	55	55	39	30	58	76	149
4.1	2	12	3	2	20	13	25	21	29	37	46	33	17	35	75	116
4.2		13	4		7	23	21	31	37	33	46	34	17	30	89	113
4.3		12	5	2	12	6	15	39	44	21	36	43	17	20	98	100
4.4		10	2		3	8	13	54	46	21	36	61	12	11	113	118
4.5		5				5	5	54	33	19	31	40	5	5	92	90
4.6		3	1			3	6	37	18	5	20	37	4	3	61	62
4.7		1	1			4	4	41	25	2	14	32	2	4	70	48
4.8		3	1		2		4	33	15	5	8	29	4	2	52	42
4.9								27	8	1	1	15			35	17
5.0		4					1	35	7		1	15	4		43	16
5.1		1						19	3			12	1		22	12
5.2						1		17	4			6		1	21	6
5.3								15	3			4			18	4
5.4		1				1		7				1	1	1	7	1
5.5								10							10	
5.6									1						1	
5.7								1							1	
5.8																
5.9																
6.0									1						1	
Total	309	368	373	413	546	410	487	464	381	435	447	477	1050	1369	1332	1359
Median	3.11	3.63	3.40	3.29	3.62	3.67	3.74	4.63	4.34	3.96	4.13	4.42	3.39	3.55	4.28	4.16
Q	.24	.35	.27	.23	.23	.28	.25	.28	.25	.25	.25	23	.33	.27	.39	.29

TABLE 28

EXPERIMENT 19: DRAWING 6″ LINES WITH EYES CLOSED. SUBJECT WO: DISTRIBUTION OF RESPONSES AT EACH SITTING

Response	Frequency in Sittings															
	1	2	3	4	5	6	7	8	9	10	11	12	1–3	4–6	7–9	10–12
3.3			1										1			
3.4																
3.5																
3.6		2	1										3			
3.7		1											1			
3.8	1	2	1			2							4	2		
3.9	4	4	4										12			
4.0	5	4	8		1	1							17	2		
4.1	6	6	5		1								17	1		
4.2	16	9	4	1	2								29	3		
4.3	22	13	6	1	2	1							41	4		
4.4	14	14	10	4	4	1			1				38	9	1	
4.5	19	18	8	3	2	1					1		45	6		1
4.6	11	10	15	6	2	2			2	1			36	10	2	1
4.7	16	17	17	11	10	7	1		1	1	1		50	28	2	2
4.8	21	20	24	17	13	3	1		4	3	1		65	33	5	4
4.9	20	20	19	20	21	4	4		7	2	4		59	45	11	6
5.0	23	20	36	34	29	14	5	1	16	10	4		79	77	22	14
5.1	18	26	34	30	25	24	6		21	14	3		78	79	27	17
5.2	17	18	26	37	35	18	7	1	22	18	11		61	90	30	29
5.3	23	23	35	35	47	24	5	1	28	20	11	3	81	106	34	34
5.4	12	20	22	38	37	28	12	3	20	41	27		51	103	35	68
5.5	12	16	24	43	43	34	14	14	23	42	32	5	52	120	51	79
5.6	9	17	9	41	32	38	25	10	31	40	52	4	35	111	66	96
5.7	9	16	13	35	40	31	29	22	18	39	43	17	38	106	69	99
5 8	6	8	3	32	29	37	20	20	18	22	64	21	17	98	58	107
5.9	5	5	1	20	24	40	25	32	24	26	38	32	11	84	81	96
6.0	8	8	3	14	23	29	41	52	34	28	53	34	19	66	127	115
6.1	2	5	2	10	11	16	42	37	28	11	35	41	9	37	107	87
6 2	1	1	1	4	10	13	45	32	16	4	27	37	3	27	93	68
6.3	2	2	1	1	15	11	40	43	14	6	16	43	5	27	97	65
6.4		2			5	5	34	36	17	4	7	43	2	10	87	54
6.5			1	2	5	5	17	22	4	3	7	38	1	12	43	48
6.6			1		5	6	16	16	10	3	3	26	1	11	42	32
6.7	1		1		2	1	21	17	4	2		33	2	3	42	35
6 8						2	11	7	2	1	3	19		2	20	23
6.9						3	6	6	2			10		3	14	10
7.0						2	1	6	1			8		2	8	8
7.1								5	1	1	1	4			5	6
7.2						1		1				1		1	2	1
7.3						1						1		1		1
7.4																1
Total	303	327	336	439	475	405	428	384	369	342	444	421	966	1319	1181	1207
Median	4.88	5.11	5.12	5.45	5.51	5.60	6.14	6.20	5.75	5.65	5.85	6 34	5.08	5.55	6.08	5.95
Q	.42	.40	.27	.24	.31	.29	.30	.24	.38	.24	.22	.26	.36	.31	.33	.31

TABLE 29

SUMMARY OF EXPERIMENTS 5 TO 19. THE INFLUENCE OF REPETITION: DRAWING LINES WITH EYES CLOSED

	Number of Repetitions			Divergence of Median from Right Response: in inches			Frequency of Initially Most Frequent Response: in percents			Variability Around Median Response (Q): in inches		
	Early	Intermediate	Late	Early	Late	Improvement	Early	Late	Change	Early	Late	Change
T 2″ a	100	750	100	− .45	− 04	+ .41	26	7	−19	.26	.13	−.13
T 4″ a	100	750	100	−1 65	− 91	+ .74	23	0	−23	.24	.22	− 02
T 6″	100	750	100	−2 64	−1.81	+ 83	25	2	−23	36	.21	−.15
T 8″	100	750	100	−3.47	−2 17	+1 30	22	0	−22	.37	.27	−.10
T 2″ b	193	3410	202	− 37	− .79	− .42	24	1	−23	.11	.08	− 03
T 4″ b	175	1836	192	+1 23	+ 96	+ 27	29	20	− 9	.16	.20	+.04
LH 4″	186	1583	145	−1 58	− 42	+1 16	32	0	−32	.20	.30	+.10
HH 4″	383	3275	289	− .05	+ .30	− .25	21	10	−11	.26	.20	−.06
Br 6″	238	2385	247	−1 53	−1.75	− .22	25	21	− 4	.38	.20	−.18
R 2″	601	4015	334	− 50	− .10	+ .40	28	14	−14	.19	.30	+.11
R 4″	554	3480	320	−1.15	−1.07	+ 08	29	0	−29	.23	.16	−.07
R 6″	545	3095	342	−2.08	−1.32	+ .76	33	0	−33	.31	.42	+.11
W 2″	133	1020	294	− 23	+ .93	− .70	20	0	−20	.48	.35	−.13
W 4″	114	1201	116	−1.18	+1.64	− .46	19	0	−19	.29	.43	+.14
W 6″	93	1032	133	−1 19	+ .93	+ 26	27	0	−27	.42	.37	−.05
Wo 2″	324	5077	623	− 71	−1.09	− 38	25	4	−21	.12	.08	−.06
Wo 4″	309	4324	477	− .89	+ .43	+ .46	21	0	−21	.24	.23	−.04
Wo 6″	303	3949	421	−1.12	+ .34	+ .78	21	0	−21	.42	.26	−.11

Experiment 20

Experiment 20 was arranged as a possible improvement on Experiments 5 to 19 by making the external situation more uniform within each subject's repetitions and more alike for all subjects. The subject was seated blindfolded at a table, on which lay a drawing-board, along the left-hand edge of which a strip of veneer two inches wide had been fastened in such a way that a large sheet of cross-section paper (16″ by 21″) could be slipped between it and the board and fastened to the board by tacks. The strip of veneer served as a fixed starting edge for drawing all lines. The cross-section paper was so ruled as to make it easy to measure the length of any line drawn. The subject was instructed to draw lines of 3, 4, 5, and 6 inches, starting always from the strip of veneer at the left. A series of 150 each of 3″, 4″, 5″, and 6″ lines was drawn daily for seven days. The series was made up of sequences of from four to eight of the same length, these sequences following one another in an order which was random, but was always used on each of the seven days.

Twelve college undergraduates, all women, served as subjects.

TABLE 30

SUMMARY OF DISTRIBUTIONS OF THE RESPONSES IN THE FIRST AND LAST HALVES OF EXPERIMENTS 8 TO 19

The quantities 1, 2, 3, 4, etc., represent groups of responses which are the same for any one subject drawing any one length, but not for different subjects or for different lengths.

Frequencies in First and Last Halves of Tables 17 to 28

Quantity	Table 17		Table 18		Table 19		Table 20		Table 21		Table 22	
	First	Last	First	Last	First	Last	First	Last	First	Last	First	Last
1			.8				.1					
2	2.0		9.6	.9	.8	.5	3.8	.9			.2	
3	21.1	3 1	21.1	9.4	16 0	35.8	19.7	6.6	12.0		25 9	
4	37.4	37.2	32.3	29.8	38.0	57.1	35.5	14.4	37.8	1.2	37.0	1.8
5	24.8	49 1	22.9	37.3	27 0	6.5	26.6	15 5	26.5	12 1	22 6	18.0
6	12.4	10 1	8.0	18.5	12.7		11.1	14.2	20.5	46.6	7.8	47.4
7	2.3	.5	3.2	3.7	5.3		2.6	16 8	3.0	31.5	5.0	26.6
8			1.2	.5			.5	14.4	.1	8.1	1.5	6.2
9							.1	9 2		.5	.1	.1
10								4.7				
11								2.4				
12								.7				
13								.1				

Quantity	Table 23		Table 24		Table 25		Table 26		Table 27		Table 28	
	First	Last	First	Last	First	Last	First	Last	First	Last	First	Last
1			1.6		.2		.1	.6				
2	.7		14.2		5.6		5.6	25 6	1.7		5.4	.4
3	29.3	1.1	25.6	1.3	18.3	.9	35.1	54.8	24.6	1.3	22.6	4.4
4	32.4	31.9	34.1	26.8	34.9	18.2	41.2	16.7	50.2	19.8	29.2	15.1
5	25.1	48.9	18.7	48.2	24.7	50.2	13.8	1.9	21.1	43.2	21.9	28.2
6	11.6	15.0	5.6	21.0	13.4	28.7	3.7	.3	2.1	29.7	8.5	31.6
7	.9	3.1	.3	2.7	2.8	2.0	.4	.1	.3	5.9	1.8	16.1
8							.0+			.1	.3	4 0
9							.0+				.1	.2
10							.0+					

For six of the twelve subjects we have four tables like Tables 17 to 28. These twenty-four tables have been studied by us, but are omitted here for lack of space. They show the same general features as Tables 17 to 28. The connections involved do not constitute a static system, but are highly unstable. The most frequent does not increase at the expense of the less frequent, and there are notable shifts of central tendency. The variability does decrease. The records of the other subjects have been studied carefully as regards the first 150 and the last 150 responses. We present a summary comparison of the first and the last sittings of all twelve subjects (Table 31), and a set of condensed distributions of the first three and the last three sittings for six subjects (Table 32). As between the first and last sittings, the most frequent responses in the first gain in only seven out of forty-eight cases. There is a tendency to stereotypism; the variability around the median response decreases in thirty-nine cases out of forty-eight, the median

TABLE 31

THE INFLUENCE OF REPETITION: DRAWING LINES WITH EYES CLOSED METHOD—BOARD

Early and late refer to the first and last sittings, or to approximately the first 150 and last 150 of the 1050 repetitions of each length

Subject		Divergence of Median from Right Response (in inches)			Frequency of Initially Most Frequent Response (in percent)			Variability Around Median Responses (Q in inches)			Variability Around Right Response (A.D. in inches)		
		Early	Late	Improvement	Early	Late	Change	Early	Late	Change	Early	Late	Change
C	3″	− .82	− .32	+ .50	33	5	−28	.47	22	− .25	.89	.45	− .44
	4″	− .85	− 16	+ .69	31	25	− 6	.47	.34	− .13	97	.46	− .51
	5″	− .97	+ .07	+ 90	22	7	−15	.73	.35	− .38	1.09	.46	− .63
	6″	− .66	+ .06	+ .60	29	27	− 2	.73	.53	− .20	1.01	.62	− .39
M	3″	+ .48	+ 29	+ 19	48	39	− 9	.36	.28	− .08	.58	.38	− .20
	4″	+ .16	+ 25	− .09	36	32	− 4	.41	.42	+ .01	.55	.54	− .01
	5″	− .04	+ 65	− 61	34	15	−19	.45	.43	− .02	.53	.72	+ .19
	6″	− .02	+1.14	−1.12	49	10	−39	.43	.52	+ .09	.57	1.13	+ .56
P	3″	+ .54	− .27	+ 27	27	4	−23	.60	.18	− .42	.87	.38	− .39
	4″	+1.29	+ 20	+1 09	33	1	−32	.75	.32	− .41	1.43	.42	−1.01
	5″	+1 53	+ 64	+ .89	33	1	−32	1.36	.45	− .91	1.72	.62	−1.10
	6″	+2.40	+ .33	+2.07	24	5	−19	1 96	.54	−1.42	3.53	.61	−2.92
R	3″	+ .41	+ .22	+ 19	34	45	+11	.45	.23	− .22	.66	.32	− .34
	4″	+ 61	+ 33	+ 28	33	58	+25	60	.26	− .34	.82	.40	− .42
	5″	+ .87	+ 77	+ .10	34	34	0	.69	.48	− .21	1.08	.84	− .24
	6″	+1 47	+1.09	+ .38	29	34	+ 5	.86	.50	− .36	1.63	1.09	− .54
S	3″	− .64	+ 35	+ 29	57	9	−48	.32	40	+ .08	.70	.55	− .15
	4″	− .73	+ .69	− 04	33	1	−32	.38	.44	+ .06	.80	.76	− .04
	5″	− 49	+2.30	−1.81	38	1	−37	.52	.59	+ .07	.78	2.21	+1.43
	6″	− 75	+2 24	−1 49	30	0	−30	.61	.45	− .16	.95	2.21	+1.26
W	3″	+ 21	+ 85	− .61	30	18	−12	.53	.32	− .21	.66	.82	+ .16
	4″	+ .34	+ 89	− .55	41	27	−14	.41	.36	− .05	.60	.93	+ .33
	5″	+ 14	+1.23	−1.09	34	8	−26	.59	.57	− .02	.64	1.27	+ .63
	6″	+ .08	+ .86	− .78	30	14	−16	.57	.62	+ .05	.72	.98	+ .26
L	3″	− .33	− .97	− .60	33	9	−24	.29	.18	− .11	.50	1.04	+ .54
	4″	− .69	−1 64	− 95	40	3	−37	.29	.20	− .09	.81	1.63	+ .82
	5″	−1.07	−2 02	−1.05	33	1	−32	.31	.17	− .14	1.03	2.06	+1.03
	6″	−1 32	−2.61	−1.29	30	9	−21	.48	.39	− .09	1.33	2.61	+1.28
T	3″	+1.32	+ .44	+ .88	26	31	+ 5	.61	.35	− .26	1.36	1.41	+ .05
	4″	+1.76	+1.56	+ .20	30	33	+ 3	.78	.48	− .30	1.62	1.53	− .09
	5″	+1 71	+3 20	−1.49	26	20	− 6	.87	.61	− .26	1.87	3.05	+1.18
	6″	+2 04	+3 03	− .99	29	23	− 6	.88	.82	− .06	2.27	3.02	+ .75
D	3″	+ 39	− 47	− .06	30	39	+ 9	.81	.23	− .58	.93	.51	− .42
	4″	− 12	− .85	− .73	28	24	− 4	.76	.28	− .48	.92	.91	− .01
	5″	− 02	−1 27	−1 25	30	14	−16	.63	.31	− .32	.83	1.29	+ .46
	6″	− .75	−2 02	−1.27	29	26	−03	1.11	.28	− .83	1.25	2.04	+ .79
J	3″	+ .03	− .16	− .13	38	41	+ 3	.26	.21	− .05	.31	.29	− .02
	4″	− 09	− .43	− .34	43	19	−24	.24	.25	+ .01	.33	.50	+ .17
	5″	− .27	− .24	+ .03	37	33	− 4	.34	.31	− .03	.51	.42	− .09
	6″	− .24	+ 02	+ .22	35	32	− 3	.47	.38	− .09	.59	.43	− .16
DB	3″	+ .97	+1.16	− .19	35	25	−10	.43	.32	− .11	.97	1.21	+ .24
	4″	+ .70	+1.27	− .57	28	9	−19	.66	.54	− .12	1.04	1.27	+ .23
	5″	+1.42	+1 78	− .36	26	25	− 1	.71	.56	− .15	1.44	1.79	+ .35
	6″	+2 16	+2.63	− .47	26	24	− 2	.84	.73	− .11	2.02	2.67	+ .65
C	3″	−1 06	− .74	+ 32	30	8	−24	.24	.21	− .03	1.11	.69	− .32
	4″	−1 47	−1.38	+ .09	28	19	− 9	.20	.30	+ .10	1.50	1.34	− .16
	5″	−1.81	− 91	+ 90	33	7	−26	.27	.40	+ .13	1.86	1.00	− .86
	6″	−2 35	−1.20	+1.15	30	3	−27	.38	.35	− .03	2.43	1.26	−1.17

TABLE 32

SUMMARIZED DISTRIBUTIONS OF RESPONSES IN THE FIRST THREE AND LAST THREE SITTINGS OF EXPERIMENT 20

The quantities 1, 2, 3, 4, etc., are equal intervals for any one subject drawing any one length, but not for different subjects or different lengths

	Frequency								Frequency							
Quan-	3"		4"		5"		6"		3"		4"		5"		6"	
tity	First	Last	First	Last	First	Last	First	Last	First	Last	First	Last	First	Last	First	Last
Subject C									Subject P							
1	10		9		22		7		9	2	2		16		4	
2	57	12	29	7	59	21	30	4	16	23	22	9	27	7	21	
3	100	141	76	65	105	155	91	60	79	231	59	146	104	171	52	52
4	170	223	167	173	164	211	157	207	173	165	175	250	152	218	174	310
5	94	70	106	151	72	49	110	134	110	28	127	43	88	39	91	83
6	18	1	46	47	15	8	52	37	43	1	57		46	1	51	6
7			7	3	1		8	5	15		3		15		24	
8			2						2				1			
Total	449	447	442	446	438	444	455	447	447	450	445	448	449	436	417	451
Subject M									Subject R							
1	4		6	2	11	3	3		3							
2	21	30	31	54	41	18	24	5	26	20	13	4	12	13	11	6
3	107	192	116	150	93	72	127	77	63	179	64	136	69	133	74	133
4	223	187	160	147	149	169	192	190	164	196	163	256	143	214	173	267
5	78	40	105	71	113	115	81	139	109	49	122	46	110	78	119	43
6	15	3	24	22	36	49	19	39	54	8	59	1	82	11	62	2
7	2		4	1	5	10			12		22		25		10	
8						2			3		2		4			
9									1							
10									1							
Total	450	452	446	447	448	438	446	450	436	452	445	443	445	449	449	451
Subject S									Subject W							
1	1		1		5		1		7		3	2	4		1	
2	33	12	13	4	87	1	83		57	11	29	10	33	4	25	3
3	103	89	124	95	125	40	90	23	93	45	114	47	144	43	103	32
4	151	168	173	196	160	194	167	99	142	135	158	95	174	138	161	104
5	115	122	111	116	67	161	90	240	93	154	85	147	75	175	110	125
6	33	44	10	25	4	39	15	72	45	91	42	69	19	83	35	112
7	9	13	3	8			2	13	6	10	10	53		12	7	50
8	5	2							2	1		8			5	14
9												5				
10												1				
Total	450	450	444	444	448	435	448	447	445	447	441	437	449	455	447	440

reduction being 6 percent of the early variability. There is no improvement; twenty-two shifts of the median are toward the correct values; twenty-six are away from them. The average error is less in twenty-six cases and greater in twenty-two.

As between the first three and the last three sittings, using the sequence of responses which is most frequent in the first three and has a frequency of about 40 percent, there are fifteen cases of increase in the last three sittings and nine of decrease. If we combine these twenty-four cases with the twelve cases of Tables 17 to 28, there are sixteen cases of increase and twenty of decrease.

As a check upon these results seven individuals drew a 4″ line five thousand times or more, five individuals did so four thousand to five thousand times, eight individuals did so from three thousand to four thousand times. They were given the same instructions, but were not supervised, and, being students of varying degrees of scientific training, may have been less careful in following the instructions.

The measurement and scoring of the lines was done as described for the earlier experiments. Since there is no demonstrable difference among these three groups in respect to the matters at issue, we combine the results.

The function is susceptible to change, the mean length shifting about as noted in the earlier experiments.

There is a moderate amount of tendency toward stereotypism, in the sense that the variability of the last hundred or next to the last hundred tends to be less than the variability of the first or second hundred.

There is no evidence that the initially most frequent responses gain more than the initially less frequent. The lengths most frequently drawn in the first hundred and comprising then from 22 to 31 of the hundred (with a median of 25½), are more frequent in the last hundred in only two of the twenty cases. Their frequencies vary then from 0 to 28, with a median of 5½. The lengths most frequently drawn in the second hundred and comprising then from 20 to 29 of the hundred (with a median of 25½) are more frequent in the last hundred in only one of the twenty cases. Their frequencies vary then from 0 to 32 with a median of 3½. If we use the first two hundred combined and the last two hundred combined, the facts are: The originally most frequent lengths, occurring in from 19 to 29 percent of the first two hundred with a median of 25 percent, are more frequent in the last two hundred in only one case out of the twenty. Their frequencies vary then from 0 to 35 percent with a median of 4½ percent.

The results for twelve individuals drawing 2000 to 3000 lines and nine individuals drawing 1000 to 2000 lines show similar general results. There is much shifting of means. The variability decreases somewhat. The lengths which were the most frequent, with median occurrences of 25 per hundred in the first hundred and second hundred, fall to medians of 12 and 11, respectively, in the last hundred. The lengths which were the most frequent in

the first two hundred, with a median occurrence of 25 percent, have a median occurrence of 11 percent in the last two hundred.

All the facts for all these forty-one individuals are shown in Table 33.

The shifting of the mode thus far outweighs any influence of the stronger tendencies to wax stronger at the expense of the weaker.

The foregoing treatment is incomplete in three respects. Theoretically, the results of the shifts of the distribution, especially in so far as they are steadily in one direction, should be allowed for, so as to leave a picture of what would happen to the responses to the same situation repeated again and again if there were no general drift toward greater length, or toward closer approximation to the true length as a central tendency. Also the effect of the chance error of the measurements upon the decision that such and such were, for the first hundred or two hundred or five hundred, the most frequent responses, should be allowed for. In the third place, the comparison of the gross variabilities when the means are different is, of course, subject to complicating factors.

I have not made allowance for the shifts because I could not tell with any surety when to make such allowance or how much allowance to make. That is, it seemed impossible to distinguish mere unexplainable shifts from regular shifts. I have not dealt with the effect of the chance error because it is too small to affect the general conclusion. I have not eliminated the complicating factors in the measurements of variability because the relation of variability to magnitude in lines drawn under the conditions of the experiment is not known, and the gain from finding out what it is seemed not worth the trouble involved. The argument here is not that, if a person drew several thousand lines in which each successive hundred clustered around the same mean, the variability of the later hundreds would not be altered from that in the first. It is that in point of fact the most frequent responses in the first hundred or two hundred or ten hundred do not become more frequent in later hundreds.

The former argument cannot well be made in the case of line drawing, and can be made easily and safely in the case of experiments to be described later.*

* Any one who wishes to make the attempt in the case of the drawing of lengths will find all the relevant data in the tables. I venture to caution

TABLE 33

Results of check experiment in drawing 4″ lines

Lengths are expressed in tenths of an inch. The entries under *Most frequent responses* are the including lengths. That is, 55 57 means, 5.5, 5.6, and 5.7 inches; 39 42 means 3.9, 4.0, 4.1, and 4.2 inches. Grouped by number of lines drawn.

Individual and number of lines drawn	Most frequent responses in first hundred	Percent of occurrence	Most frequent responses in second hundred	Percent of occurrence	Most frequent responses in last hundred	Percent of occurrence	Most frequent responses in next to last hundred	Percent of occurrence	Percent of occurrence in the last hundred of the responses which were most frequent in the first hundred	Percent of occurrence in the last hundred of the responses which were most frequent in the second hundred	A.D. first hundred	A.D. second hundred	A.D. last hundred	A.D. next to last hundred	Most frequent responses in first two hundred	Percent of occurrence	Most frequent responses in last two hundred	Percent of occurrence	Percent of occurrence in the last two hundred of the responses which were most frequent in the first two hundred
5000																			
S B E	53 54	22	55 57	25	39 41	29	38 39	28	0	1	3.9	4.0	3.6	2.1	53 55	25	39 40	26.5	0.5
J C E	38 40	31	40 42	27	38 40	28	48 50	25	28	5	3.2	3.8	3.2	3.4	38 40	28.5	42 44	23.5	14
M E	54 56	23	45 46	20	40 41	24	39 40	22	0	9	4.9	3.6	3.1	3.2	46 48	22	39 40	22.5	4
M M R	44 46	30	42 44	27	33 35	26	37 38	23	5	12	4.5	4.0	3.9	3.7	44 46	27.5	35 37	29	5
H L L	17 18	27	14	26	39 41	25	37 38	26	0	0	2.4	1.2	5.6	2.2	15	19	39 41	25	0
N L	25 26	23	30 31	27	29 31	25	33	21	17	16	3.1	2.7	3.4	1.6	28 30	27	32 33	28	17
I S	46 48	28	41 45	25	39	20	36 37	30	1	11	4.1	9.9	2.6	2.3	46 48	19.5	37 38	26.5	2
4000–5000																			
M I C	35 37	27	31 33	20	39 40	22	40 41	26	20	0	3.3	3.6	3.4	3.5	33 35	25	39 40	21	7
S M E	23 24	27	25 26	26	36 37	23	36 37	29	6	0	2.2	2.3	3.2	2.6	24 25	25.5	37 38	22	0
H C N	20 21	26	24	23	33	21	36 37	26	0	0	3.0	2.4	2.3	2.4	23 24	24.5	34 36	28	0
E F M	40 41	27	44 45	28	40 41	24	43 44	20	24	23	2.5	3.1	2.3	3.0	42 44	29	42 43	23	35
H V P	42 44	25	52 54	24	42 44	21	46 47	26	21	5	4.1	5.1	3.6	3.4	42 44	22	45 47	26	21

3000–4000																									
B C	38	39	22	41	43	25	41	42	23	44	45	26	12	32	3.2	3.7	3.0	2.6	40	42	28.5	44	45	24.5	25.5
E C	33	34	25	24		25	44	45	27	43	44	26	0	0	3.0	2.5	2.4	2.8	28	30	22.5	43	44	25	0.5
S M S	31	32	26	33	34	29	40		25	41	42	29	0	1	2.9	2.6	1.9	2.3	31	32	22	41	42	28	0
A H	39	41	22	37	38	28	41	42	23	42	44	24	25	9	3.5	2.8	5.0	4.4	38	40	24	41	43	28	12.5
M M S	28	29	25	32	33	24	44	46	24	38	40	23	0	1	2.4	3.0	4.3	3.8	29	31	27	44	46	22	2
W F	42	43	22	36	37	27	50	51	28	50	51	24	4	1	2.6	2.3	4.0	3.7	38	40	26	50	51	26	4
T W	41	42	30	44		20	39	40	26	38	39	26	20	1	2.8	2.5	2.5	2.5	42	43	24	38	39	27	13.5
J V W	40		22	33	35	26	35	37	26	39	40	21	16	21	3.1	4.3	3.7	3.5	35	37	27.5	38	40	26	24
2000–3000																									
A K A	17		23	19	20	28	30		18	33	34	22	0	0	2.3	1.9	2.1	2.8	17		20	30	31	24	0
L D C	35	37	24	34	35	25	36	37	21	40		25	28	5	4.1	2 9	3.3	1.9	33	35	26	39	40	29	9
J F	24	25	24	25	26	23	40	41	26	42	43	24	0	0	2.8	2.4	2.7	2.3	24	25	27	40	41	26	0
E G	30	31	30	32	33	21	37		21	33	34	28	5	23	2.8	3.2	2.4	2.7	30	31	25	36	37	24	6
L G G	38	39	26	37	38	26	38	39	25	37	38	30	25	30	2.8	2.5	2.2	2.1	37	38	26.5	37	38	28.5	28 5
L J	37	39	20	48	50	23	59	60	27	60	61	20	0	2	4.8	4.3	2.9	3.3	44	46	19	59	60	25	0
W F S	24	25	27	22		21	23	24	28	21	22	23	34		2.6	1.8	1.9	2.3	23	24	28	24	25	27.5	21.5
N S	38	40	29	40	41	24	35	36	29	41	42	22	31	18	3.3	2.9	2.6	4.1	38	40	28	38	40	27	27
A O M	38	39	24	36	37	22	34	35	33	35		20	10	11	3.6	2.9	2.3	2.6	37	39	25	35		19	16
A M H	38	39	28	38	39	31	42	43	26	39	40	23	15	17	2.3	2 0	2.9	3 0	38	39	30.5	40	41	26	16
C P T	30	31	27	25	26	24	32	33	23	31	32	26	9	3	2.1	3.1	3.9	2.7	27	29	25	32	33	22	19
R L	38		23	39	40	33	37	38	28	37	38	24	16	25	3.0	2.4	2.4	2.3	38	39	29.5	38	39	28	28
1000–2000																									
C C	36	37	22	38	39	26	30		19	32		19	4	0	2.7	2.9	2.0	1.8	38	39	26	30		18	0
V M E	36	37	24	36	37	21	31		25	32	33	30	7	13	2.7	4.9	1.9	2.1	35	36	23	31	32	29	14
F	31	32	26	30	31	27	26		22	26	27	22	12	11	2.9	2.7	2.0	3.5	30	31	24	26	27	27	9
H S H	35	37	23	37	38	28	35	36	25	30	31	28	34	2	2.6	2.6	2.4	2.6	37	38	26	32	33	23	6
E S	40	41	24	37		24	32		20	32	33	30	2	7	2.9	1.7	2.1	2.1	37	38	29	31	32	26	8
C T Y	45	46	24	49	51	20	38	40	24	44	45	21	12	11	3.3	5.4	6 9	3.0	44	46	24	43	45	24	23
C T W	43	43	23	43	44	29	39	40	27	41		26	16	6	3.0	2.4	2.3	1.7	43	44	26	43	45	24	23
D F	35	37	24	36	37	25	27	29	28	25		18	2	0	4.8	3.4	3.2	1.9	36	37	21	24	25	24	0
M B W	38		26	37		20	38		20	38	39	29	20	18	2.0	2.6	2.1	1.8	38	39	30	38	39	29	29

Experiments 21 and 22

Experiments 21 and 22 were of the same general plan as Experiments 5 to 20, but with angles drawn instead of lengths. In Experiment 21, subject T responded with eyes closed to the situations, *Draw an angle of 20°; Draw an angle of 45°; Draw an angle of 60°.* Eight hundred and nine sets of three angles* were drawn

TABLE 34

Experiment 21: drawing 20° angles with eyes closed. Subject T: Distribution of responses in groups of two sittings, in groups of four sittings, and in groups of eight sittings

Response: in degrees	Frequency in Sittings 1, 2	3, 4	5, 6	7, 8	9, 10	11, 12	13, 14	15, 16	1–4	5-8	9-12	13-16	1-8	9-16
4			1			1				1	1		1	1
5			1							1			1	
6		1							1				1	
7			2	1						3			3	
8		1	7		1	3			1	7	4		8	4
9	4	4	8		5	5	1	1	8	8	10	2	16	12
10	2	10	15		4	2	2	4	12	15	6	6	27	12
11	8	9	11	8	4	12	3	3	17	19	16	6	36	22
12	8	12	12	9	12	13	5	7	20	21	25	12	41	37
13	11	22	12	11	9	10	12	8	33	23	19	20	56	39
14	9	21	18	9	7	15	13	11	30	27	22	24	57	46
15	8	10	5	15	19	10	20	15	18	20	29	35	38	64
16	4	5	2	11	8	9	12	10	9	13	17	22	22	39
17	13	6	3	9	9	3	12	13	19	12	12	25	31	37
18	12	1	3	9	12	1	10	9	13	12	13	19	25	32
19	6	4		10	2	3	3	6	10	10	5	9	20	14
20	2			6	4	2	3	7	2	6	6	10	8	16
21	2		2	4	3	2	1	2	2	6	5	3	8	8
22	1			2	1		2	1	1	2	1	3	3	4
23	3			4		1		1	3	4	1	1	7	2
24	2			1				1	2	1		1	3	1
25	1	1	1					1	2	1		1	3	1
26							1	1				2		2
27	1								1				1	
Total	97	107	103	109	100	92	100	101	204	212	192	201	416	393
Median	15.8	13.8	12.5	16.1	15.4	14.0	15.7	16.1	14.3	14.3	14.7	15.9	14.3	15.4
Q	2.6	1.4	2.0	2.6	2.4	1.9	1.7	2.1	2.3	2.0	2.1	1.9	2.4	2.1

such a one that it will *not* be profitable to select those cases where a certain hundred or two hundred or other fraction of the total number drawn has the same mean as a certain fraction drawn earlier. This selection will be unfair since it favors greatly those cases where the response which was the most frequent at one stage was the most frequent at another stage. It thus favors the increase of the most frequent, since if the most frequent response becomes still more frequent, the mode and mean will stay the same, but if it becomes less frequent the mode and mean may shift.

* Except that occasionally by a lapse, some one of the sequence of the three was omitted or repeated.

in sixteen sittings. No angle was seen until all had been drawn. The angles were measured to 1°, the general directions of the lines being determined when either was curved or bent, by a procedure which was only approximate, but was uniform throughout. The results appear in Tables 34, 35, and 36.

In the case of the 20° and 45° angles, there was some shifting of the mean, but not large and not constantly in one direction. There is no evidence of strengthening of the more frequent at the expense of the less frequent. The variability is not reduced. In the case of the 60° angles, there is a marked shift to larger angles beginning with the seventh sitting. The variability is not reduced (median of first eight Q's = 3.3°; of last eight, 3.25°).

Experiment 22 consisted of the drawing of 3600 angles of 45°

TABLE 35

EXPERIMENT 21: DRAWING 45° ANGLES WITH EYES CLOSED. SUBJECT T: DISTRIBUTION OF RESPONSES IN GROUPS OF TWO SITTINGS, IN GROUPS OF FOUR SITTINGS, AND IN GROUPS OF EIGHT SITTINGS

Response	Frequency in Sittings													
	1, 2	3, 4	5, 6	7, 8	9, 10	11, 12	13, 14	15, 16	1–4	5–8	9–12	13–16	1–8	9–16
12					2						2			2
13			1		1					1	1		1	1
14		3			3				3		3		3	3
15		4	4	2	6	2			4	6	8		10	8
16	1	2	3		4	2			3	3	6		6	6
17	3	7	6	4	6			1	10	10	6	1	20	7
18	2	5	8	2	3	3	1		7	10	6	1	17	7
19	9	7	11	4	10	1	2		16	15	11	2	31	13
20	8	13	7	8	8	1	6	1	21	15	9	7	36	16
21	8	4	7	3	6	6	9	9	12	10	12	18	22	30
22	8	9	10	16	8	6	8	12	17	26	14	20	43	34
23	7	12	12	10	12	7	9	12	19	22	19	21	41	40
24	8	15	11	16	7	5	6	10	23	27	12	16	50	28
25	8	11	6	11	1	6	14	9	19	17	7	23	36	30
26	6	2	6	5	7	2	3	8	8	11	9	11	19	20
27	6	6	2	5	9	6	9	6	12	7	15	15	19	30
28	6	3	5	11	7	8	8	9	9	16	15	17	25	32
29	6	2	1	6		3	6	6	8	7	3	12	15	15
30	2		2	2		5	8	8	2	4	5	16	6	21
31	5	1		2		8	4	2	6	2	8	6	8	14
32	2			1		6	2	4	2	1	6	6	3	12
33			1				3	2		1		5	1	5
34	1			1			1	1	1	1		2	2	2
35						2		1			2	1		3
36	1					1			1		1		1	1
37						3					3			3
38		1				1			1		1		1	1
39						1					1			1
40	1					2	1		1		2	1	1	3
41						4					4			4
Total	98	107	103	109	100	91	100	101	205	212	191	201	417	392
Median	24.1	22.9	22.5	24.3	22.1	27.8	25.6	25.6	23.5	23.5	23.9	25.6	23.5	25.0
Q	3.2	2.6	2.8	2.5	3.0	4.2	3.1	2.9	2.8	2.7	3.9	2.9	2.7	3.3

by Br in twelve sittings, no angle being seen. The results appear in Table 37. There is a shift to larger angles. There is no increase of the frequent responses at the expense of the rare.

TABLE 36

Experiment 21: drawing 60° angles with eyes closed. subject T: Distribution of responses in groups of two sittings, in groups of four sittings, and in groups of eight sittings

Response	Frequency in Sittings 1, 2	3, 4	5, 6	7, 8	9, 10	11, 12	13, 14	15, 16	1–4	5–8	9–12	13–16	1–8	9–16
14 and 15		1							1				1	
16 and 17														
18 and 19														
20 and 21		1							1				1	
22 and 23	1	1	1						2	1			3	
24 and 25	2	4	4	1					6	5			11	
26 and 27	2	4	3	2					6	5			11	
28 and 29	12	12	8	1					24	9			33	
30 and 31	14	15	13	8	4				29	21	4		50	4
32 and 33	24	10	20	7	5	3			34	27	8		61	8
34 and 35	15	15	14	18	11	1			30	32	12		62	12
36 and 37	6	14	16	12	9	1	2		20	28	10	2	48	12
38 and 39	10	11	9	21	19	3	7	1	21	30	22	8	51	30
40 and 41	3	5	7	11	22	8	12	2	8	18	30	14	26	44
42 and 43	4	8	4	16	11	5	10	13	12	20	16	23	32	39
44 and 45	1	2	2	6	11	12	20	15	3	8	23	35	11	58
46 and 47	2	1	1	2	2	5	14	13	3	3	7	27	6	34
48 and 49		2	1	1	4	15	14	16	2	2	19	30	4	49
50 and 51		1		2	1	11	6	14	1	2	12	20	3	32
52 and 53					1	8	5	9			9	14		23
54 and 55						8	5	9			8	14		22
56 and 57				1		2	3	6		1	2	9	1	11
58 and 59							1	2				3		3
60 and 61						4	1				4	1		5
62 and 63						1					1			1
64 and 65						3		1			3	1		4
66 and 67						1					1			1
68 and 69						1					1			1
Total	96	107	103	109	100	92	100	101	203	212	192	201	415	393
Median	33.4	34.6	34.4	38.4	40.1	48.8	45.9	48.8	33.9	36.5	42.9	47.2	35.3	45.7
Q	2.7	4.0	3.2	3.6	2.7	4.4	3.5	3.5	3.5	3.4	4.9	3.4	3.7	4.5

TABLE 37

EXPERIMENT 22: DRAWING 45° ANGLES WITH EYES CLOSED. SUBJECT BR: DISTRIBUTION OF RESPONSES BY SITTINGS, AND BY GROUPS OF THREE SITTINGS

Response	Frequency in Sittings															
	1	2	3	4	5	6	7	8	9	10	11	12	1–3	4–6	7–9	10–12
8 and 9	1												1			
10 and 11	4												4			
12 and 13	12		1										13			
14 and 15	28	3		2									31	2		
16 and 17	34	1	4	1	1								39	2		
18 and 19	54	10	4	3		1							68	4		
20 and 21	54	15	8	8	8								77	16		
22 and 23	50	43	26	22	4							1	119	26		1
24 and 25	35	52	35	31	17	1							122	49		
26 and 27	25	46	43	31	26	5	1			2		1	114	62	1	3
28 and 29	17	72	48	56	32	5	1	1	5	1			137	93	7	1
30 and 31	8	48	53	59	27	6		1	3	3		2	109	92	4	5
32 and 33	7	29	34	42	44	10	1	5	8	6	3	2	70	96	14	11
34 and 35	3	13	23	28	42	20	7	9	9	11	1	4	39	90	25	16
36 and 37		11	13	12	27	19	13	15	14	8	5	2	24	58	42	15
38 and 39	1	7	13	1	25	32	20	30	14	15	4	3	21	58	64	22
40 and 41			3		20	34	20	31	28	14	4	4	3	54	79	22
42 and 43			1		17	38	24	33	24	20	11	7	1	55	81	38
44 and 45					7	38	46	16	32	25	20	9		45	94	54
46 and 47					8	29	31	22	29	32	15	20		37	82	67
48 and 49			1		2	12	39	23	28	28	19	17	1	14	90	64
50 and 51					3	15	22	26	27	32	34	23		18	75	89
52 and 53						11	29	31	31	22	35	28		11	91	85
54 and 55					1	4	19	25	14	25	32	35		5	58	92
56 and 57					1	5	2	13	8	16	29	29		6	23	74
58 and 59						2	4	13	9	9	23	22		2	26	54
60 and 61							1	7	6	8	23	18			14	49
62 and 63						2		3	3	3	10	17		2	6	30
64 and 65								1	2	1	5	10			3	16
66 and 67								1	1		1	7			2	8
68 and 69										1	1	4				6
70 and 71											1	3				4
72 and 73											1					1
74 and 75												1				1
76 and 77												1				1
Total	333	350	310	296	312	289	280	306	295	282	277	270	993	897	881	829
Median	20.1	27.1	28 3	28.8	32.9	41.6	45.7	46.1	45.8	47.2	52.3	54.0	26.38	34.13	46.87	52.15
Q	3.3	3.1	3.2	2.9	4.5	4.0	4.1	6.1	5.2	4.7	4.7	4.9	3.95	5.70	5.22	5.28

APPENDIX III

Experiments in connecting numbers with words

Experiment 24

Experiment 24 was of the same general nature as Experiment 23, but was improved in several respects. First, twelve words were used instead of six. (*Admire* and *bread* occurred sixty times each; *able, answer, beast, cannot, difference, fatar, freshness, happy, meaning,* and *elevate* occurred forty times each.) These 440 situations were scattered throughout 3400 other words, making a total list of 3840. They thus occurred more rarely than did the experimental words in Experiment 23. Only 320 words were presented at any one sitting, there being twelve sittings, one each day from June 14 to 29, except on Saturdays and Sundays. Any one of the twelve words was presented five, three, two, or zero times a day. The time schedule was thus more like the schedules of actual learning than was the case with Experiment 23.

There were six subjects, all women, college undergraduates. They received the following instructions:

"You may think of the experiment which we are to do as an experiment in thought transference; it has other uses also. I will read words at the rate of two per five seconds. As I say each word I will think of a number from 0 to 9. If you can get by telepathy the number which I am thinking, please write it. If you do not get the one that I think of, write the first one that occurs to you. Be sure it is a number smaller than 10, that is, a number of one figure. I will be able to tell whether you have got the number of which I am thinking by whether your answer agrees with my key."

After the first 320 words instructions were simplified to "Thought transfer again." The second trial emphasized not waiting too long for the "transfer"—since the first time some had failed to respond because the experimenter read the next word before they had recorded a number.*

* Arrangements were made to locate any omissions and in all respects to be sure that the records showed which number each subject wrote for each occurrence of each word.

For each subject we have a record like that shown in Table 43.

TABLE 43

FREQUENCIES OF RESPONSES TO *admire*, *bread*, *able*, *answer*, ETC., IN SUCCESSIVE TENS. SUBJECT C

Admire

0						
1		1				
2	2					
3	2	1		1		1
4	2					
5	2		1		1	
6	1	3	1	3	3	1
7	1	2		1		
8		3	4	5	6	8
9			4			

Answer

0	1	1		
1	1	3		4
2	1	4	6	5
3	2		1	
4		1		
5	1		1	1
6	2		1	
7	1	1		
8				
9	1		1	

Difference

0	3	6		
1	1			
2				1
3				
4	1	1		
5	3			1
6	2	3	10	5
7				1
8				1
9				1

Happy

0	1			
1			1	
2	3		1	1
3	2	2		
4			2	1
5		1	1	
6	2	2	5	4
7		1		2
8	1	4		2
9	1			

Bread

0						
1	2	1				
2	3					
3	4	7	10	10	9	10
4	1	1				
5						
6					1	
7						
8						
9		1				

Beast

0				
1	5		2	
2	5	7	7	10
3			1	
4		1		
5				
6				
7		2		
8				
9				

Fatal

0	9	7	10	7
1				
2				
3		1		
4		2		
5				
6	1			2
7				
8				
9				1

Meaning

0				
1	2	3	1	2
2	5	4	9	6
3	1			
4		1		
5	1	1		
6		1		1
7	1			
8				1
9				

Able

0		2		
1	1			
2	1			
3	2	2	1	4
4	3	3	6	1
5		1		1
6	2		1	3
7	1		2	
8				1
		2		

Cannot

0	7	9	6	3
1			1	1
2				
3	1	1		
4				
5	1			
6	1		1	6
7			2	
8				
9				

Freshness

0	3			
1	1	1	1	1
2				
3	1	1		
4	1			
5	1	1		
6	1	1	3	6
7	1	2		1
8	1	3	5	2
9		1	1	

Elevate

0				
1	1			
2				
3	2			
4	2			
5				
6	4	4	1	
7				1
8		6	9	9
9	1			

We begin the analysis of the results by constructing Table 44, which is of the same nature as Table 41. The responses with a frequency of 4, 5, 6, or 7 in the first twenty do not increase their frequency in later tens. Of the twenty-four "4" cases, twenty-two are less than 3. Of the ten "7" cases, nine are less than 3.

The "1," "2," "3," "4," "5," and "6" cases which compete with them do a little better; 61 percent show a falling off, compared with 73 percent for the initially most frequent.

The responses with frequencies of 8 to 17 in the first twenty gain slightly in late tens. The sixteen in the "8, 9, 10" group show eight cases above 4.5. The twenty-four in the "9, 10, 11" group show twenty above 5.0. The twelve in the "12, 13, 14" group show nine above 6.50. The fourteen in the "15, 16, 17" group show seven above 8.0. These total forty-four out of sixty-six, and there was one the same in both. The initially infrequent

responses competing with them show only ten increases (and one equal) out of fifty-four chances.

We next compare the most frequent response in the first twenty with its competitors, in respect of the gain in the fourth ten over the third, in the fifth ten over the fourth and in the sixth ten over the fifth.

TABLE 44

THE AVERAGE NUMBER OF OCCURRENCES IN EACH TEN, AFTER THE FIRST TWENTY, OF RESPONSES WHICH OCCURRED 4 TIMES, 5 TIMES, 6 TIMES, ETC., IN THE FIRST TWENTY

In Comparison with similar facts for responses which occurred 0 times, 1 time, 2 times, etc., in the first twenty, in the same individual, to the same word

Responses to *Admire* and *Bread*

1st 20	3rd 10	4th 10	5th 10	6th 10	1st 20	3rd 10	4th 10	5th 10	6th 10
4	.40	1.20	1.80	.40	0	1.60	1.20	.00	.40
4	1.00	3.00	3.00	1.00	1	.00	.00	.00	.00
4	.60	1.80	2.20	.60	2	.20	.20	.40	.00
4	.43	1.29	1.86	.43	3	1.43	1.43	2.00	2.43
5	2.38	2.88	3.50	2.75	0	.88	.75	.25	.38
5	2.38	2.50	1.81	.88	1	1.00	.63	.38	.88
5	3.62	2.85	2.35	1.46	2	.54	.85	1.00	.62
5	2.00	2.75	3.13	1.25	3	1.50	1.00	1.50	2.50
5	2.00	2.50	2.25	2.50	4	1.00	.50	.50	.00
6	1.00	.00	.00	1.00	0	.75	1.50	.75	.50
6	1.00	.00	.00	1.00	1	1.33	.33	1.67	1.33
6					2				
6					3				
6	1.00	.00	.00	1.00	4	2.00	2.00	1.00	1.00
6	1.00	.00	.00	1.00	5	1.00	1.00	1.00	2.00
9, 10, 11	8.23	6.29	7.14	7.50	0	.08	.22	.29	.00
9, 10, 11	7.83	5.00	6.33	6.50	1	.00	.67	.17	.17
9, 10, 11	8.67	8.00	9.67	10.00	2	.33	.00	.00	.00
9, 10, 11	10.00	10.00	9.00	10.00	3	.00	.00	.00	.00
9, 10, 11					4				
9, 10, 11	8.00	7.00	10.00	10.00	5	.00	.00	.00	.00
9, 10, 11					6				
9, 10, 11	7.00	2.00	3.00	3.00	7	3.00	4.00	3.00	6.00
17	9.00	5.50	5.50	8.50	0	.17	.50	.42	.17
17	9.00	5.50	5.50	8.50	1	.00	.50	.67	.17

Responses to *Able*, *Answer*, etc.

1st 20	3rd 10	4th 10	1st 10	3rd 10	4th 10
4	1.25	1.54	0	.67	.50
4	1.45	2.38	1	.95	.30
4	1.36	2.04	2	1.07	1.13
4	1.21	1.63	3	.97	1.12
5	1.91	2.97	0	.68	.45
5	2.03	3.18	1	.78	.60
5	1.70	2.09	2	.88	1.30
5	2.18	3.03	3	.95	.70
5	1.63	3.00	4	1.38	.75
6	2.06	1.69	0	.81	.81
6	2.64	1.57	1	.64	.86
6	2.50	1.67	2	.75	1.00
6	1.60	1.00	3	.60	.60
6	3.75	2.75	4	1.50	1.75
6	1.00	1.67	5	2.00	1.33
7	.00	2.50	0	1.00	.83
7	.00	2.00	1	1.40	.80
7	.00	2.50	2	.25	1.25
7	.00	5.00	3	1.00	1.00
7	.00	2.50	4	2.50	.00
8, 9, 10	4.75	4.53	0	.31	.53
8, 9, 10	7.86	7.86	1	.18	.18
8, 9, 10	4.12	4.00	2	.18	.12
8, 9, 10	4.00	4.00	3	.60	.20
8, 9, 10	7.50	9.50	4	.50	.00
8, 9, 10	3.33	2.33	5	3.67	2.67
8, 9, 10	1.00	.00	6	9.00	9.00
8, 9, 10	9.00	9.00	7	.00	.00
12, 13, 14	6.67	7.44	0	.24	.24
12, 13, 14	6.00	6.55	1	.55	.45
12, 13, 14	5.20	7.60	2	.40	.40
12, 13, 14	8.00	4.00	3	.00	.00
12, 13, 14	7.50	7.00	4	1.00	1.00
12, 13, 14	7.00	10.00	5	2.00	.00
15, 16, 17	8.16	6.78	0	.11	.22
15, 16, 17	8.30	7.10	1	.40	1.00
15, 16, 17	8.00	6.85	2	.33	.17
15, 16, 17			3		
15, 16, 17	8.00	6.00	4	.00	1.00

The most frequent shows forty-eight cases of gain, thirteen of no change and thirty-seven of loss; its competitors show thirty-one cases of gain, twenty-six of no change and forty-one of loss.

Combining the results for Experiments 23 and 24 we have:

	Changes for 3rd to 4th ten, 4th to 5th ten, etc.			
	Gain	Equal	Loss	Gain + ½ Equal
Most frequent response in the first 20	110	24	125	122
Its competitors	94	55	110	121.5

On the whole, Experiments 23 and 24 show no waxing of the frequent at the expense of the infrequent except in some of the cases where the frequency runs above 70 percent. The gains which then sometimes accrue seem explicable as the results of the formation of meaningful, or otherwise impressive, associations such as bread 8, answer 2, cannot 0. As soon as the subject realizes that certain words are being repeated often, (say after five repetitions) he has a tendency to pay especial heed to them, to think about them, and so to form associations which relieve the strain of the general task by furnishing convenient easy responses. If such an association is formed during the repetitions 6 to 15, and always acts thereafter, it will of course show histories like these:

		Frequency in	
	First 20	Third 10	Fourth 10
Association formed in repetition 6	15 or more	10	10
" " " " 7	14 or more	10	10
" " " " 8	13 or more	10	10
" " " " .	.	.	.
.	.	.	.
" " " " 15	6 or more	10	10

It will be the most frequent in the first twenty and will almost always gain. In the experiments such histories will be modified by various other factors, but the general effect will be the same. Evidence that this happens is the fact that the responses of high frequency in the first twenty gain in later twenties over the first twenty, but not in the fourth ten over the third ten, or in the fifth ten over the fourth.

In these experiments in responding to a word by a number, the variability of the responses to a word decreases as the experiment progresses, although the originally strong connections gain little or nothing from the originally weak. We may measure this re-

duction in variability crudely by the number of different responses occurring in an early ten and a late ten, respectively. Thus we find that individual "A" used 5, 6, 7, 8, 6 and 6 different numbers in his first ten responses to *and, the, are, in, is* and *of*, respectively, and 4, 3, 5, 3, 2 and 5 different numbers in his last ten responses to them. A random sample of fifty of the individuals whose records constitute Tables 38, 39, and 41, used 570 different numbers in the first ten responses to *and* and *are*, and 453 different numbers in their last ten responses to them. For *the* the corresponding numbers were 280 and 202; for *in, is,* and *of* they were 861 and 683.

We may measure the reduction more exactly by comparing the distributions of the frequencies in the first ten with the distribution of the frequencies in the last ten. We find that the number of responses occurring only once or twice drops, and the number of responses occurring eight or nine or ten times rises. For fifty individuals taken at random from those whose records constitute Tables 38, 39, and 41, the facts are shown in Table 45.

TABLE 45

THE REDUCTION IN VARIABILITY IN EXPERIMENT 23: DISTRIBUTIONS OF THE FREQUENCIES OF THE FREQUENCIES 1 TO 10

	Responses to *and* and *are*		Responses to *the*		Responses to *in, is,* and *of*	
	In the first 10	In the last 10	In the first 10	In the last 10	In the first 10	In the last 10
1	299	238	140	86	455	333
2	168	101	85	60	264	181
3	70	47	36	15	91	71
4	16	20	15	16	29	26
5	13	9	2	4	14	26
6	2	12	2	3	2	8
7	2	7		7	4	12
8		4		5		14
9		9		2	2	6
10		6		4		6

In the case of Experiment 24, we report the facts for each successive ten. The numbers of different responses used for *admire* and *bread* were, in order, 63, 55, 51, 56, 50, and 38; the numbers for *able, answer,* etc., were, in order, 323, 294, 279, and 250. The frequencies of the frequencies in this experiment were as shown in Table 46 and Table 47.

As these tables show, there is in both experiments selection for survival, producing a certain amount of stereotypism, but not of

the initially strong at the expense of the initially weak. This is what happened in the case of judging lengths and drawing lines.

TABLE 46

THE REDUCTION IN VARIABILITY IN EXPERIMENT 24: DISTRIBUTIONS OF THE FREQUENCIES OF THE FREQUENCIES 1 TO 10 IN SUCCESSIVE TENS FOR *admire* AND *bread*

	First 10	Second 10	Third 10	Fourth 10	Fifth 10	Sixth 10
1	39	31	26	29	25	17
2	11	11	12	14	11	8
3	5	6	5	6	7	4
4	3	1	2	2	1	
5	2	1	1	1	1	1
6	1		..	1	1	1
7		2	1	1		1
8	2	1	1			1
9		2	2	1	3	1
10			1	1	1	4

TABLE 47

THE REDUCTION IN VARIABILITY IN EXPERIMENT 24: DISTRIBUTIONS OF THE FREQUENCIES OF THE FREQUENCIES 1 TO 10 IN SUCCESSIVE TENS FOR *able*, *answer*, ETC.

	First 10	Second 10	Third 10	Fourth 10
1	176	148	159	128
2	79	85	61	56
3	39	34	21	25
4	12	12	7	6
5	9	1	5	7
6	2	2	5	7
7	5	5	6	2
8		3	6	2
9	1	4	7	6
10		2	2	10

APPENDIX IV

Materials and results for experiment 38, with the *Angel* word number series

TABLE 129

Words and numbers used in *angel* test I* with number of occurrences

	48	24	12	12	6	6	6	6	3	3	3	3	3	3	3	3
act		10														
angel		51	41	96	35	26	62	74	19	27	52	73	77	81	87	93
ape									45							
atom		47	36	73												
bake		32	24	68	37	49	73	84								
bandage					41	89										
bend			64													
cadet			16													
call			42													
city			48		14	58										
come			31		11	23			13	27	98	99				
crew			49		36	75										
cube									27							
date			96													
deplore					82											
dog		91														
ease					79											
fish			76		50	58										
fog			29	83												
gem			74													
grand		81	17	76	12	16	25	35								
half									50							
hand			26													
hexagon					88											
home			54		36	97			15	35	57	83				
include			81		25	83										
lace			22													
likeness					94											
lips									63							
loose			84													
manage					15											
mention									27							
money			96		32	70										
name			25													
old			67		24	72			12	56	85	97				
pack									80							
pole		96														
pound									16							
prince			26													
push	42															
rank		74														
riches			46		23	75			11	25	49	74				
roman					37	54										
rose					19	27	43	69								
saddle					85											
secure		91	16	62												
shall			74													
shoes			22													
stem	64															
table			93													
tag					91											
thirty									30							
total			95													
try		27	53	82	17	47	65	96	12	29	32	41	48	56	62	71
unlucky									13							
wagon					93											
wet		28														

* This table is read *act-10* occurred 24 times; *angel-51*, 24 times; *angel-41*, 12 times; etc.

TABLE 130

Words and numbers used in *angel* test II* with number of occurrence

	48	24	12	12	6	6	6	6	3	3	3	3	3	3	3	3
apart		76														
basin			47													
bonus					81											
brooks									76							
brown					90											
clock					21	32	68	96								
den			63													
digest					33	98										
drift		63	25	62	13	22	43	94	15	27	28	72	78	89	91	96
each			80		50	76			14	36	81	82				
empty			72													
envy			94													
foot									12							
flood		55	47	98	13	14	51	56								
fortify					83											
frank			59		53	99										
hat			22													
hopeful		58	48	84												
hunt					89											
ice			73													
last									99							
lily			28		48	92										
many			47													
mint		28														
morsel			92		15	74										
move		79	50	95												
parish			18		24	68										
play					42	88										
praise		42	32	76	34	35	58	86	16	31	37	49	54	63	68	97
pulley					23											
quick		47														
quarter									25							
rain			91													
remnant					92											
rope			36													
sailor					86											
same		95														
score									20							
skin		28														
small			27													
spoil									32							
stone		29	80	93	37	38	83	99								
strong			17	53												
tact					87											
thief			37		26	84										
tone			76													
various									42							
want			79		43	71			24	52	57	73				
wish	48															
with			74													
yard					93				14	78			36			
nail			93													
neither			16		26	41			22	78	79	88				
nerve					84											
never			52													
horse			21		12	64										

* This table is read *apart-76* occurred 24 times; *basin-47*, 12 times; etc.

TABLE 131

FREQUENCY OF NUMBERS IN THE *angel* EXPERIMENT

Second Digit	First Digit 1	2	3	4	5	6	7	8	9	Total
0	30	6	0	6	36	6	9	33	6	132
1	21	21	24	39	42	15	43	60	99	364
2	44	63	65	111	38	39	45	39	47	491
3	27	53	21	38	51	72	102	57	85	506
4	34	41	24	15	48	83	127	60	38	470
5	39	60	39	12	51	12	31	18	54	316
6	78	64	68	45	36	6	64	41	96	501
7	38	78	54	126	12	18	28	18	29	401
8	18	127	21	90	57	33	18	18	27	409
9	15	67	9	40	21	12	57	15	24	260
Total	344	580	325	522	392	296	524	362	505	3850

TABLE 132

EXPERIMENT 38: THE NUMBER OF CORRECT RESPONSES FOR WORDS IN THE *angel* SERIES FOLLOWED BY A SINGLE NUMBER

Occurrences			Group B n=13	Group A n=8
48	push	42	5	3
	stem	64	4	0
	wish	48	6	4
24	act	10	9	6
	apart	76	5	0
	dog	91	5	1
	mint	28	1	1
	pole	96	5	0
	quick	47	2	0
	rank	74	3	1
	same	95	3	1
	skin	28	6	6
	wet	28	7	2
12	basin	47	0	0
	bend	64	2	0
	cadet	16	7	8
	call	42	1	0
	date	96	5	1
	den	63	1	0
	empty	72	1	0
	envy	94	0	0
	gem	74	0	2
	hand	26	2	1
	hat	22	5	1
	ice	73	3	0
	lace	22	3	1
	loose	84	0	0
	many	47	3	2
	nail	93	4	0
	name	25	5	1
	never	52	1	0
	prince	26	6	2
	rain	91	2	1
	rope	36	1	0
	shall	74	1	1
	small	27	3	3
	shoes	32	7	3
	table	93	1	0
	tone	76	1	1
	total	95	7	4
	with	74	2	0
6	bonus	81	1	0
	brown	90	4	2
	deplore	82	0	0
	ease	79	0	0
	fortify	83	1	0
	hexagon	88	5	6
	hunt	89	0	0
	likeness	94	0	0
	manage	15	1	4
	nerve	84	1	0
	pulley	23	3	1
	remnant	92	1	1
	saddle	85	0	0
	sailor	86	1	3
	tact	87	0	1
	tag	91	1	0
	wagon	93	0	0
3	ape	45	0	1
	brooks	76	0	3
	lips	63	1	2
	mention	27	1	0
	spoil	32	1	1
	various	42	0	3
3 Meaningful				
	cube	27	5	1
	foot	12	5	1
	half	50	3	3
	last	99	0	1
	pound	16	10	1
	quarter	25	8	4
	score	20	5	3
	thirty	30	1	6
	unlucky	13	12	7

TABLE 133

EXPERIMENT 38: THE NUMBER OF CORRECT RESPONSES IN THE *angel* SERIES, IN THE CASE OF WORDS FOLLOWED BY MORE THAN ONE NUMBER

Word	Group	1 Number 24 Occurrences	2 Numbers 12 Occ. Each	4 Numbers 6 Occ. Each	8 Numbers 3 Occ. Each	Total Responses
angel	A	4	6	2	8	27
	B	6	3	0	1	18
drift	A	0	1	0	2	11
	B	2	1	2	0	14
praise	A	0	0	0	1	10
	B	2	1	0	2	14
try	A	2	0	1	0	10
	B	3	0	2	1	13
Total for four		19	12	7	15	
bake	A	0	1	1		9
	B	5	1	1		15
flood	A	0	0	1		8
	B	11	0	2		15
grand	A	1	0	1		10
	B	1	6	2		15
stone	A	3	4			11
	B	4	4			14
Total for four		25	16	8		
atom	A	4	1			
	B	4	2			13
hopeful	A	1	3			
	B	2	4			13
move	A	1	2			
	B	1	5			15
secure	A	3	2			
	B	0	3			14
Total for four		16	22			
come	A	1	2	1		9
	B	1	7	2		15
each	A	1	1	2		11
	B	1	3	1		14

TABLE 133 (*Continued*)

Word	Group	1 Number 12 Occurrences	2 Numbers 6 Occ. Each	4 Numbers 3 Occ. Each	Total Responses
home	A	1		1	9
	B	2		3	15
neither	A	1			9
	B	1			13
old	A	1	2	0	12
	B	1	2	3	18
riches	A	0	3	2	12
	B	1	2	1	14
want	A	0	0	0	8
	B	1	1	1	13
Total for seven		14	23	17	
city	A	2	0		8
	B	3	1		13
crew	A	2			8
	B	6			13
fish	A	0	1		8
	B	3	3		14
frank	A	2	3		10
	B	2	3		16
include	A	1	0		8
	B	1	3		14
lily	A	2			9
	B	5			17
money	A	1	2		8
	B	4	0		13
morsel	A				8
	B				13
parish	A	1			9
	B	2			14
thief	A	1	3		10
	B	1	3		15
Total for ten		39	22		

TABLE 133 (*Continued*)

Word	Group	2 Numbers 12 Occurrences	Total Responses
fog	A	2	8
	B	5	13
strong	A	1	8
	B	7	13
		4 Numbers 6 Occurrences	
clock	A	2	11
	B	3	15
rose	A	6	11
	B	4	13
		2 Numbers 6 Occurrences	
bandage	A	0	8
	B	1	13
digest	A	2	10
	B	3	14
play	A	0	8
	B	2	13
roman	A	0	8
	B	3	13

*

APPENDIX V

Experiments in learning code substitution

Experiment 90

The Code Substitution Material (I. E. R.—C. L. 1 to 20) which was compiled for this experiment consists of twenty pages. At the top of each page is the Tilton Code shown below, a letter for letter code, and a selection, taken from the *Encyclopedia Britannica*, to be transcribed into the code. Each page reproduced by multigraph was mounted on quadrille-ruled paper so that the subject could record each letter in a quarter-inch square, as shown in the sample on page 540 (reduced to one-fourth the original dimensions). Mimeographed copies of the directions were read silently by the subjects, while the experimenter read them aloud. The directions were: "This is an experiment to see how people use a letter code. On the page that follows there will appear a code and some material to be written in the code. Below the material to be coded is the cross-section paper on which you are to write, putting in each quarter-inch square the appropriate code letter, translating from the paragraph. Leave no blank square between words or sentences. Omit all punctuation. Work as fast as you can without making mistakes. *Do not* tear this page off until the signal is given."

After reading the directions the experimenter asked the subject, "Is that clear?" After a pause to answer any question, the order *Go* was given. At the end of one minute, the subjects were told to stop.

The number of letters correctly transcribed constituted the score of the page.

The three groups (composed of students at Teachers College) practicing the code substitution material were equated on the basis of the mean score at the first trial. Thereafter each group practiced code substitution under its own condition of distribution. One group (Cont.) practiced twenty minutes without the intervention of any interval of time between successive practices, while another group (Min.) had a constant interval of one minute regularly interpolated after each minute of practice, and a third group

I. E. R. - C. L. -11-

For:	a	b	c	d	e	f	g	h	i	j	k	l	m
Write:	g	t	y	r	l	j	w	p	v	o	u	n	h
For:	n	o	p	q	r	s	t	u	v	w	x	y	z
Write:	a	z	s	m	f	x	q	k	d	e	c	i	b

Few orators belonging to the Church of England have acquired so great a reputation as Liddon. Others may have surpassed him in originality, learning or reasoning power, but for grasp of his subject, clearness of language, lucidity of arrangement, felicity of illustration, vividness of imagination, elegance of diction, and above all, for sympathy with the intellectual position of those whom he addressed, he has hardly been rivalled.

(Day) had a constant time interval of twenty-four hours regularly interpolated after each minute of practice.

Seventy-five seconds after the last practice period, each individual of each group was presented with a form (I.E.R.—C. L. xx Ra., shown below) on which he was to reproduce the code. Probably no subject ever studied the code as such. During the experiment proper and during the twenty minutes of work emphasis was placed primarily on the directions "Work as fast as you can without making mistakes."

When a subject was scanning the code to find the equivalent of a letter, there was, of course, some possibility of noting the equivalents of other letters. The ones so noted would probably be especially those next to the ones looked for, and those at the margins

a m n and z
↓ ↓ ↓ ↓
g h a b

The equivalent of *q* (*m*) is recalled more often than chance would permit; as also is that for *z* (*b*) though *z* was never required to be substituted for; likewise that for *a* is remembered oftener than those for other letters of equally frequent occurrence. The main strengthening of the connections $a = g$, $b = t$, $c = y$, etc., was however, by the direct attention to that part of the code, and the retention of the fact long enough to use it, and by memory checked or not checked by attention to the code after the subject came to know, or think that he knew, certain equivalents.

I. E. R.—C. L. xx Ra.

You are to reproduce the code that you have been using in this series. You will be given the alphabet as it was printed in the training series. Write the proper code equivalent below each letter. Guess if necessary. There should be an equivalent for every letter.

a b c d e f g h i j k l m

n o p q r s t u v w x y z

Do *not* discuss this phase of the experiment with any one.

The number of occurrences of each letter in the coding and the number of individuals recalling the letter in the test is shown for each of the three groups in Table 134.

When the results are arranged by groups of four occurrences we

have the facts of Table 135. When the percentages for records without *a, m, n,* and *z* are combined with equal weight, we have column 8 of Table 135. When they are combined with a weight of 3 for the Day group, 2 for the Min. group and 1 for the Cont.

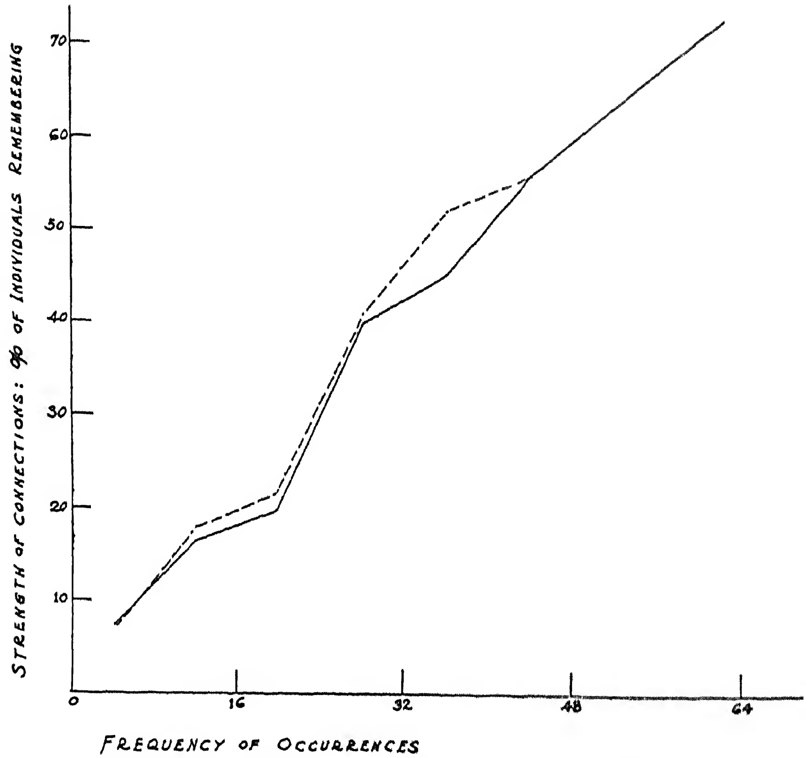


FIGURE 16. The relation between frequency of occurrence and the resulting strength of connections. The continuous line shows the average of the three groups with equal weights, whereas the dotted line shows the average using weights of 3, 2, and 1, respectively, for the Day, Min., and Cont. groups.

group, we have column 9 of Table 135. The two curves of Figure 16 show these results combined for 0 and 4, 8 and 12, 16 and 20, 24 and 28, 32 and 36, 40 and 44, and 56, 60, and 64. There is no evidence of any diminution in returns. One repetition seems to count equally, regardless of what it is added to.

TABLE 134

EXPERIMENT 90: RESPONSES IN CODING LETTERS OF THE ALPHABET. THREE EQUATED GROUPS

	Day Group		Min. Group		Cont. Group	
	Average No. of Times Coded	Number Recalling Code Equivalent	Average No. of Times Coded	Number Recalling Code Equivalent	Average No. of Times Coded	Number Recalling Code Equivalent
a	42.5	22	43.2	20	35.8	33
b	7.2	1	6.9	2	6.2	7
c	21.3	2	21.6	6	18.5	8
d	16.2	2	16.5	6	14.7	7
e	66.3	16	64.0	15	56.6	24
f	10.5	1	9.5	4	8.3	7
g	10.6	1	10.5	2	9.0	6
h	30.7	9	29.2	8	25.7	15
i	31.4	12	30.9	9	27.7	18
j	3.8	0	3.8	0	3.5	3
k	2.7	0	2.5	2	2.3	1
l	23.0	3	22.3	4	21.0	9
m	13.9	4	13.5	8	11.9	17
n	35.9	17	35.7	18	31.6	29
o	46.5	10	45.0	13	41.1	17
p	6.0	4	5.7	2	4.5	0
q	1.0	2	0.9	1	0.9	2
r	31.7	4	31.5	9	26.8	9
s	41.9	15	41.6	15	37.2	26
t	37.4	3	36.6	11	32.2	21
u	21.0	5	20.9	6	18.8	9
v	5.3	1	5.3	0	4.3	0
w	6.8	1	6.7	3	5.2	1
x	1.0	1	1.0	1	0.8	2
y	3.2	3	3.0	2	2.6	3
z	0.0	2	0.0	3	0.0	3

TABLE 135

THE RELATION OF STRENGTH OF CONNECTION TO NUMBER OF OCCURRENCES

Occurrences in Coding	Percentages of Individuals Recalling in the Test							
	Day Group		Min. Group		Cont. Group		Ten Times Average of 3, 5, 7	
1	2	3	4	5	6	7	8	9
	All Letters	All but a, m, n, z	All Letters	All but a, m, n, z	All Letters	All but a, m, n, z	Equal Weights	Weights of 3, 2, 1.
0*	5	5	8½	7	7	7	63	60
4	7	7½	9	9	6	6	75	84
8	4	4	22½	22½	30	20	153	128
12	17		40		21	21	210	210
16	8	8	25	25	26	26	197	167
20	15	15	30	30	27	27	240	220
24					42	42	420	420
28	35	35	42½	42½			388	380
32	71		67½	45	82	64	545	513
36	13	13	55	55	79	79	490	380
40	77	63	100		51	51	570	600
44	42	42	65	65			535	512
48								
52								
56					73	73	730	730
60			75	75			750	750
64	67	67					670	670

* 0 means from 0–3.99; 4 means from 4–7.99; etc.

APPENDIX VI

Materials for experiments on the polarity of connections

A 1–40 (words also used in B, 121–160)

aby..	camou.....	emph....	gend....	paja...
baci....	accom.....	pana...	samu...	airp....
bach....	cala....	card....	mart....	taff...
epis...	hamad....	acrop....	desul....	bisc...
fov..	oppro.....	jonq...	balus.....	fau...
marq...	ambus....	kod..	albat....	heca....
canta.....	frag...	maud...	lumb...	orche....
gonf....	pano....	broi...	mauso....	nouv...

B 1–40 (words also used in A, 121–160)

....uito	....atis	....aulin	...izon	.....lesce
...olu	....itar	...cher	....aden	...icot
....ster	....duct	...elon	....amon	....ntula
...ight	....orant	...naco	...cere	....hyst
....gham	....lind	....rban	...tund	....auche
...lea	.....ecary	.....quish	...nium	....nder
....apose	....ssin	.....agora	....chus	....rney
...ora	....odile	....baga	....liant	...lum

A 41–80 (words also used in B, 81–120)

bewi....	cale....	ecst...	goss....	macki.....
catec....	obel...	rab..	bop...	brac....
alum...	peng...	celi....	taber.....	chinc.....
cere....	taci....	chev...	labyr....	rigma....
deso....	chut...	kay..	portc.....	stryc.....
elep....	clar....	larc...	scav....	alph....
haci....	tali....	rog..	tapi...	divo...
maho....	oblo...	diat....	khed...	amar....

B 41–80 (words also used in A, 81–120)

....oram	...anac	.....elier	....anese	...unia
.....uffin	...gain	....rcle	...fron	....ubim
....osia	....lenge	...berd	...bt	...bic
....udge	...ibou	...rgne	...sute	....rice
...avan	....latan	...elin	...han	...nna
...ucca	.....chino	...umen	....edary	....aroo
....eleon	...algo	...grim	....sook	...neer
....olic	....ardy	.....cheon	...nnex	....dish

A 81–120 (words also used in B, 41–80)

marj....	alma...	chand.....	manga....	petu...
ragam.....	barg...	enci....	saff...	cher....
ambr....	chall....	halb...	dou..	iam...
begr....	cari...	eper...	hirs...	lico....
cara...	charl....	jave...	orp...	due...
felu...	maras.....	bitu...	drome....	kang....
chame....	hida...	pilg...	nain....	pion...
diab....	jeop....	escut.....	rean...	blan....

B 81–120 (words also used in A, 41–80)

....lder	....ndar	...tasy	....amer	..... ntosh
....chism	...lisk	..bbi	...eep	....elet
...mnus	...guin	....bate	.....nacle	.....hilla
....brum	....turn	...vron	....rinth	....arole
....late	...tney	..yak	.....ullis	..... hnine
....hant	....inet	...ceny	....ongo	....abet
....enda	....sman	..gue	...ioca	...orce
....gany	...oquy	....ribe	...dive	....anth

A 121–160 (words also used in B, 1–40)

mosq....	clem....	tarpa....	hori...	conva....
orm...	scim....	butc...	menh....	apri...
cloi....	aque....	eche...	cinn....	taran....
slei...	cormo....	guan...	sinc...	amet....
bron....	purb....	subu....	orot...	avala....
aza...	apoth.....	relin.....	cran...	cyli....
juxta....	assa....	mandr.....	bron....	atto....
aur...	croco....	ruta....	brill....	asy...

B 121–160 (words also used in A, 1–40)

..yss	.....flage	...asis	....arme	...amas
....llus	.....plish	...acea	...urai	....lane
....elor	....bash	....inal	....inet	...feta
...sode	....dryad	....polis	....ltory	...cuit
..vea	.....brium	...quil	.....trade	...cet
...quis	....scade	..dak	....tross	....tomb
.....loupe	...gile	...dlin	...bago	....estra
....alon	....rama	...ider	....oleum	...veau

1. exeunt ____________
2. haec olim ____________ ____________
3. materia ____________
4. sunt lacrimae ____________
5. facile ____________
6. obiter ____________
7. varium et mutabile ____________ ____________
8. suppressio veri ____________ ____________
9. experimentum ____________
10. quorum pars ____________ ____________
11. jeunesse ____________
12. pari ____________
13. comme il ____________
14. quot homines ____________ ____________
15. ancien ____________
16. de mortuis ____________ ____________ ____________
17. sotto ____________
18. laborare ____________ ____________
19. casus ____________
20. raison ____________
21. et tu ____________
22. mens sana ____________ ____________ ____________
23. ars longa ____________ ____________
24. nisi ____________
25. festina ____________
26. senatus ____________
27. nolle ____________
28. mirabile ____________
29. compos ____________
30. est modus ____________ ____________
31. de gustibus ____________ ____________ ____________
32. reductio ____________ ____________
33. à perte ____________ ____________
34. gaudeamus ____________
35. similia ____________ ____________
36. aut Caesar ____________ ____________
37. mardi ____________
38. habeas ____________
39. particeps ____________
40. à propos ____________ ____________
41. faux ____________
42. per aspera ____________ ____________
43. dramatis ____________
44. natura non ____________ ____________
45. vox populi ____________ ____________
46. quién ____________
47. advocatus ____________
48. e pur ____________ ____________
49. lis ____________
50. mutatis ____________

51. bis dat __________ __________ __________
52. fortiter in re __________ __________ __________
53. lusus __________
54. panem et __________
55. honoris __________
56. ceteris __________
57. otium cum __________
58. hic __________
59. tempus __________
60. maxima debetur __________
61. crême de __________ __________
62. mors omnia __________
63. verbatim __________
64. fait __________
65. pis __________
66. ab uno __________ __________
67. danse __________
68. naturam expellas furca __________ __________ __________
69. disjecta __________
70. pons __________
71. memento __________
72. sic transit __________ __________
73. dulce et decorum est __________ __________ __________
74. arbiter __________
75. ohne Hast, __________ __________
76. enfant __________
77. ne plus __________
78. fiat justitia __________ __________
79. omne ignotum __________ __________
80. O tempora __________ __________
81. die Wacht __________ __________
82. per fas __________ __________
83. splendide __________
84. amici usque __________ __________
85. cave __________
86. rara __________
87. ignoratio __________
88. Sturm __________ __________
89. laudator __________ __________
90. perfide __________
91. burn the candle __________ __________ __________
92. ici on __________ __________
93. jacta __________ __________
94. solitude a __________
95. autres temps __________ __________
96. res angusta __________
97. de haut __________ __________
98. sine qua __________
99. nulli __________
100. odium __________

1. __________ __________ la crême
2. __________ omnia solvit
3. __________ __________ literatim
4. __________ accompli
5. __________ aller
6. __________ __________ disce omnes
7. __________ macabre
8. __________ __________ __________ tamen usque recurret
9. __________ membra
10. __________ asinorum
11. __________ __________ __________ at both ends
12. __________ __________ parle Français
13. __________ __________ alea
14. __________ à deux
15. __________ __________ autres moeurs
16. __________ angusta domi
17. __________ __________ en bas
18. __________ qua non
19. __________ secundus
20. __________ theologicum
21. __________ __________ am Rhein
22. __________ __________ et nefas
23. __________ mendax
24. __________ __________ ad aras
25. __________ canem
26. __________ avis
27. __________ elenchi
28. __________ __________ Drang
29. __________ __________ acti
30. __________ Albion
31. __________ __________ __________ cito dat
32. __________ __________ __________ suaviter in modum
33. __________ natural
34. __________ et circenses
35. __________ causa
36. __________ paribus
37. __________ cum dignitate
38. __________ jacet
39. __________ fugit
40. __________ __________ puero reverentia
41. __________ mori
42. __________ __________ gloria mundi
43. __________ __________ __________ est pro patria mori
44. __________ elegantiarum
45. __________ __________ ohne Rast
46. __________ terrible
47. __________ plus ultra
48. __________ __________ ruat coelum
49. __________ __________ pro magnifico
50. __________ __________, O mores

51. ______________ omnes
52. ______________ ______________ meminisse juvabit
53. ______________ medica
54. ______________ lacrimae rerum
55. ______________ princeps
56. ______________ dictum
57. ______________ ______________ ______________ semper femina
58. ______________ ______________ suggestio falsi
59. ______________ crucis
60. ______________ ______________ magna fui
61. ______________ dorée
62. ______________ passu
63. ______________ il faut
64. ______________ ______________ tot sententiae
65. ______________ régime
66. ______________ ______________ ______________ nisi bonum
67. ______________ voce
68. ______________ ______________ orare
69. ______________ belli
70. ______________ d'être
71. ______________ ______________ ______________ est disputandum
72. ______________ ______________ absurdum
73. ______________ ______________ de vue
74. ______________ igitur
75. ______________ similibus curantur
76. ______________ ______________ aut nullus
77. ______________ gras
78. ______________ corpus
79. ______________ criminis
80. ______________ ______________ de rien
81. ______________ tu, Brute.
82. ______________ ______________ ______________ corpore sano
83. ______________ ______________ vita brevis
84. ______________ prius
85. ______________ lente
86. ______________ consultum
87. ______________ prosequi
88. ______________ dictu
89. ______________ mentis
90. ______________ ______________ in rebus
91. ______________ pas
92. ______________ ______________ ad astra
93. ______________ personae
94. ______________ ______________ facit saltum
95. ______________ ______________ vox dei
96. ______________ sabe
97. ______________ diaboli
98. ______________ ______________ si muove
99. ______________ pendens
100. ______________ mutandis

APPENDIX VII

The influence of primacy and of recency*

It has been a common, not to say orthodox, doctrine that, other things being equal, the response which is made to a situation by an individual the first time that he encounters it becomes connected with that situation more strongly by that one experience than does any response made to any single later occurrence of the situation by that one experience.

Thus Seashore writes: "In experimental psychology a more specific formulation of laws in terms of force of the association has gained recognition. The chief of these are: (1) *primacy*: other things being equal the association first formed will prevail" ['23 p. 158]. Pillsbury writes: " . . . We find the factors that determine the strength of the connection between one element and those that have been associated with it. These have been shown to be the *frequency* with which the two elements have appeared together, the *recency* of their association, . . . and the *primacy* of the association. Professor Calkins has shown that the earlier one element enters into an association with another, the more likely it is to be recalled with that than with any other with which it has been associated at a later period" ['22, pp. 285f.].

We have subjected this doctrine to rather extensive experimental tests, the net result of which is to prove that primacy in and of itself has zero potency. We shall show, for example, that, other things being equal, an individual's second or third response to a situation is as prophetic of, and similar to, his later responses to it as his first response, and that, in a series of n recurrences of a situation, the last response is as indicative of, and similar to, responses 2 to $n - 1$ as the first response is, if other things than temporal position are kept equal.

Experiment 91

Fourteen college or graduate students estimated the lengths of 250 strips of paper, 10 of 5-inch, 10 of 5¼-inch, 10 of 5½-inch, and

* Part of this Appendix appeared in 1927 in the *Journal of Experimental Psychology,* vol. x, pp. 18-29.

so on up to 10 of 11-inch. These were presented one at a time, in a random order, being laid on a table in front of the subject, who entered his estimate for each in terms of inches and quarter-inches. No subject knew anything concerning the constitution of the series, save that each length was a multiple of ¼-inch. For each length for each person we then have a record of the ten estimates in the order of their occurrence like this for B with the 5-inch length; 3_2, 3_3, 4_1, 3_1, 4_1, 4_2, 4_0, 4_0, 4_1, 4_3 (the first digit of each number denoting inches and the second fourths-of-an-inch). If now the connection producing the response 3_2 has any special potency over behavior due to its being the first, responses of 3_2 should be more frequent in, say, the last seven of the ten than responses of 3_3 or of 4_1 (the second and third). This is on the assumption that there is zero correlation within one length for one individual between the magnitude of his estimates and their place in the series. This assumption is probably correct, but we shall check it later.

The general result of the three hundred and fifty such computations is that the 2450 responses from the fourth to the tenth displayed 550 like the first, 533 like the second, and 591 like the third. In order to have knowledge of the reliabilities of the 550, 533, and 591, we may express each as the average of five subtotals, the first computed from the facts for 5, 6_1, 7_2, 8_3, and 10_0, the second computed from the facts for 5_1, 6_2, 7_3, 9_0, 10_1, and so on. They then become 110, 106½, and 118, with mean square errors of 6.8, 4.1, and 5.7, respectively. There is thus no evidence of any special potency of the connections productive of the first response.

We can deal with the possible correlation noted above by computing the number of cases where responses I to VII were the same as response X in the series, and comparing the results with the number of cases (550) where responses IV to X were the same as response I. The correlation, if it exists, works against likeness of I to VII to X as much as against likeness of IV to X to I. The number of cases of the 2450 responses I to VII which are the same as response X is 522. Using the same procedure to express this with an estimate of unreliability as was used above, we have Average = 104½, with a mean square error of 4.9. The difference between the 522 and the 550 is less than six-tenths of its mean square error. The absence of any special potency of the connections productive of response I, due to their primacy, is then not

explainable by a contrary force due to positive correlation of the magnitude of an estimate with its position in the series.

Experiment 92

Strips of white cardboard 4 inches wide and from 12 to 28 inches long were exposed for 2 seconds at the rate of one every 5 seconds, and the subject was required to make and record an estimate in inches of the length of each. Among the strips were 12 15-inch strips, 12 18-inch strips, 12 20-inch strips, 12 22-inch strips, and 12 25-inch strips. Each subject's responses to each of these series were recorded in order. The subjects had no knowledge whether their estimates were right or wrong, except that possibly some of them might notice the ratings given by other subjects sitting near them, or get some impression from some subject who tended to whisper to himself the numbers as he wrote them down. They were cautioned about both these matters. We then observe whether the first response has any especial potency over later responses, by observing whether responses II to XI are more like response I than like response XII; or whether responses II to XI are more like response I than responses III to XII are like response II, or than responses I to X are like response XI. Our measure of likeness is the number of the ten which were given the same estimate as No. I (or XII, or II, or XI, as the case may be). The result is emphatic. The number of the ten following I which are the same as I is 937; the number of the ten following II which are the same as II is 1179; the number of the ten preceding XI which are the same as XI is 1568; the number of the ten preceding XII which are the same as XII is 1590. The first impression of a length and the first response to a length give no evidence of greater power in determining the next ten responses than the second impression and response have, or than the eleventh or twelfth have in determining the preceding ten.

If primacy had any potency it was greatly outweighed by other forces which made the first experience less indicative of the intermediate responses than the second, and both the first and the second much less indicative of the intermediate responses than were the eleventh and twelfth.

Experiment 93

Two adults (graduate students) estimated in square inches without fractions each area in a series of 121 surfaces of various sizes and shapes. There were twelve estimations, one a day for twelve days. Neither subject knew whether any estimate was right or wrong, nor, except for her memories, whether any estimate was the same as any one she had previously made for that area.

We have then 242 records like that shown below for one area.

Occurrences	1	2	3	4	5	6	7	8	9	10	11	12
Estimates	27	30	38	34	31	33	32	34	36	34	35	35

We measure the extent to which the estimates for occurrences II to XI, inclusive, were like the estimate for occurrence I, and also the extent to which they were like estimate XII. We also measure the likeness of estimates III to X, inclusive, to estimate II, and to estimate XI. Likeness is measured by the number of estimates identical with I or XII or II or XI as the case may be. The results are as shown below.

	Subj. R	Subj. W
Occurrences II to XI	1210	1210
Number like I	138	81
Number like XII	212	254
Occurrences III to X	968	968
Number like II	129	109
Number like XI	203	206

Here again there is no evidence of any superior potency of the first experience. If there is any such potency, it is far outweighed by factors which cause a reduction in the variability of the responses to the same surface.

Experiment 94

The subject, being given six sheets of paper 8½ inches by 11 inches, was told to close his eyes and draw a line 2 inches long, then below it a line 4 inches long, then below that a line 6 inches long, drawing four such sets of three on each sheet. Each line was to be drawn with one fairly quick swing of the hand. This was illustrated for him. He then closed his eyes and drew the 72 lines. The length of each was then measured to the nearest tenth

of an inch. The number out of the last twenty 2-inch lines which were of the same measured length as the first 2-inch line drawn was recorded. The number out of the last twenty 2-inch lines which were of the same measured length as the second 2-inch line drawn was recorded; and similarly for the number of the same length as the third 2-inch line drawn, and the fourth.

If the connection producing the first response to the situation "Draw a 2-inch line," has an advantage over the connection producing the second or third or fourth, by reason of being the first, and if other things are equal, the number of the responses V to XXIV like response I should be greater than the number like response IV.

Similar computations were made in the case of the 4-inch lines and 6-inch lines. Similar computations were made also for all three lengths, using the number of responses V to XXIV where the measured length diverged from that of response I or II or III or IV by 0.1 inch. The facts appear in Table 136 for fourteen adult subjects. If there were no relation between the serial order of a subject's drawings of a length and their magnitudes, this table could be taken at its face value, and would show a decided inferiority of the connection productive of the first response. There is, however, such a relation in many of the individuals, as is shown by the differences between the median length of the first 9 lines drawn and the median length of the last nine; and allowance for it must be made. Allowance can be made by comparing the potency of I, II, III, and IV on V to XXIV with the potency of XXI, XXII, XXIII and XXIV on I to XX.

We find that the influence of connections XXI to XXIV on connections I to XX is in general equal to the influence of connections I to IV on connections V to XXIV. The number of zero divergencies is 192 for the former and 185 for the latter. Corresponding numbers for divergences of one are 289 and 297. Using divergences of 0 or 1, we have 481 and 482. The influence of connection XXIV on connections I to XX is practically as great as the influence of connection I on connections V to XXIV. The zero divergences are 44 for I and 42 for XXIV; the divergences of one-tenth inch are 68 for I and 68 for XXIV also.

Experiment 94 then in no wise supports the doctrine that the first connection made with a situation is more important than any other in determining future connections.

TABLE 136

THE INFLUENCE OF PRIMACY IN THE CASE OF DRAWING LINES

Subj.	Length of First 4				No. Lines in Trials V–XXIV Equal to				No. Lines in Trials V–XXIV Differing by 0.1 inch from				Median Length of	
	I	II	III	IV	I	II	III	IV	I	II	III	IV	First 9 Lines	Last 9 Lines
							In drawing 2-inch lines							
Bre	13	20	24	23	1	2	3	1	3	3	3	3	24	20
Bu	11	11	10	10	0	0	0	0	0	0	0	0	13	22
D	11	14	15	11	6	4	2	6	5	3	5	4	13	12
F	10	8	11	13	3	1	5	3	10	5	4	2	11	11
H	9	6	5	5	0	0	0	0	5	0	0	0	9	13
K	11	9	8	11	2	1	0	2	1	0	1	1	11	17
L	6	18	18	6	9	0	0	9	4	0	0	4	6	6
M	16	19	17	20	1	2	3	5	3	7	3	4	17	20
R	10	10	9	5	2	2	1	0	1	1	2	0	10	16
Sn	18	21	25	28	0	0	2	1	1	1	3	0	25	25
Sw	6	9	10	8	0	0	3	3	1	6	6	0	9	13
V	12	21	18	16	2	1	2	4	0	0	4	7	16	17
Y	11	12	19	19	0	0	3	3	0	1	8	8	19	18
Totals					26	13	24	37	34	27	39	33		
							In drawing 4-inch lines							
Bre	39	41	45	49	1	0	1	0	2	5	1	2	45	39
Bu	23	18	21	21	0	0	0	0	4	0	1	1	23	36
D	21	26	30	30	0	2	3	3	0	1	5	5	29	30
F	19	22	24	21	0	1	1	0	0	1	1	1	24	27
H	14	15	16	17	0	0	0	0	0	0	0	0	21	26
K	30	20	23	22	1	0	0	0	5	0	1	0	26	33
L	18	20	16	14	3	2	3	2	5	2	4	4	18	16
M	38	36	29	37	1	1	0	0	0	3	3	2	36	36
R	20	25	32	21	0	1	1	0	2	1	4	1	22	30
Sn	28	35	44	49	0	0	0	0	0	1	2	1	49	46
Sw	11	15	17	13	0	1	3	0	0	0	2	0	17	22
V	27	36	29	31	1	0	3	1	2	1	4	6	31	30
Y	25	23	26	41	0	0	0	4	0	0	0	5	37	37
Totals					7	8	15	10	20	15	28	28		

TABLE 136 (*Continued*)

Subj.	Length of First 4				No. Lines in Trials V–XXIV Equal to				No. Lines in Trials V–XXIV Differing by 0.1 inch from				Median Length of	
	I	II	III	IV	I	II	III	IV	I	II	III	IV	First 9 Lines	Last 9 Lines
					In drawing 6-inch lines									
Bre	41	44	63	58	1	0	0	0	1	2	0	1	56	47
Bu	34	34	31	32	2	2	1	0	2	2	0	3	33	51
D	41	38	48	30	2	2	1	0	3	2	2	0	38	42
F	36	45	43	41	0	0	3	1	2	0	2	6	43	39
H	19	20	20	23	0	0	0	0	0	0	0	1	24	32
K	36	34	31	31	0	0	1	1	3	3	1	1	33	48
L	27	26	22	25	4	0	0	5	0	9	5	1	25	25
M	58	44	35	49	1	0	2	0	1	1	0	1	46	52
R	36	35	40	38	1	1	2	1	1	1	0	0	36	46
Sn	49	42	54	65	0	0	0	2	0	0	0	4	66	61
Sw	16	18	21	21	0	0	1	1	0	0	1	1	21	28
V	45	41	35	38	0	0	2	0	1	0	3	4	38	35
Y	26	31	40	47	0	0	2	3	0	0	1	1	47	44
Totals					11	5	15	14	14	20	15	24		
Sum of 3 totals					44	26	54	61	68	62	82	85		

Experiment 94a

Experiment 94a was the same as Experiment 94 except that only two lengths, 3-inch and 5-inch were drawn, and only twelve lines of each length. There were 124 subjects. The lines were all measured to 0.1 inch. We count the number among lines II to XI which received the same measure as line I, and the number which received the same measure as line XII. The results are: for 3-inch lines; 104 like line I, 133 like line XII; for 5-inch lines, 101 like line I, 110 like line XII. We also count those whose measures were only 0.1-inch each up or down from line I, and similarly for line XII. The results are: for 3-inch lines, 210 within 0.1 inch of line I, 225 within 0.1 inch of line XII; for 5-inch lines, 159 within 0.1 inch of line I, 174 within 0.1 inch of line XII.

Experiment 95

In Experiment 95 the external situations presented were the sound of a (as in late), ee (as in week), ou (house), o (home), aw (saw), k (kind), f (fence) and s (so). The response was, in each case, to represent the sound by a letter or letters. The sounds appeared in three-syllable nonsense words* which the subjects spelled. For each sound for each of 105 subjects, we have a record of the first twelve spellings in order.

We compare the occurrences, in responses III to X, of the spellings which were given the first time that a sound occurred, the second time, the eleventh time, and the twelfth time, respectively. The totals are 3398, 3485, 3626, and 3627. The first response thus has no advantage over the second or twelfth or thirteenth; but, on the contrary, is less potent in determining what the eight responses from the third to the tenth are to be. The lack of special potency of the first experience is seen even more closely when we eliminate the many cases where the second (or eleventh, or twelfth) spelling, as the case may be, was the same as the first. The frequencies in III to X of spellings I and II, when these are different, are 902 and 991. Those of I and XI, when these are different, are 1016 and 1237. Those of I and XII, when these are different, are 898 and 1136.

Experiment 96

Six college students added letters to make words out of 960 combinations like ca, pl, ti, de, fe, ag, *etc.*, doing 240 a day. In each day's 240, certain combinations occurred twice. For these combinations we have records of the eight completions such as are shown below:

ac	count	an	imal	ap	e
	tor		nounce		pear
	count		other		pear
	cept		on		ple
	count		t		ple
	count		imal		pear
	count		t		e
	curate		imal		point

We measure the likeness of completions II to VII, inclusive,

* *E.g.*, 1. kace eed' aub, 2. weece' o loot, 3. kawl awt eez', 4. roee' ano our, *etc.*

to completion I and to completion VIII, by counting those which are the same as I and VIII, respectively. Since there is a tendency, as the situation recurs, increasingly to favor the shorter completions, we make the comparison separately for cases where completions I and VIII were of the same length, for cases where I was a one-letter and VIII was a two-letter completion, for cases where I was a two-letter and VIII was a one-letter completion, for cases where I was a one-letter and VIII was a three-letter completion; and so on for cases of 3 and 1, 1 and 4, 4 and 1, 1 and 5, 5 and 1, 2 and 3, 3 and 2, 2 and 4, 4 and 2, *etc.*

The results are as follows: In 316 cases where the completions I and VIII were of the same length, 225 were cases where I and VIII were the same completion; in the remaining 91 cases 103 of the 546 completions were the same as completion I, 186 were the same as completion VIII, 257 being like neither. The cases where the completions I and VIII were of different length are treated by finding the average number (out of six as a possible maximum) which were like I and the average number which were like VIII. The results are shown in Table 137.

In each pair of these averages the two members are given equal weight in computing the result entered in the last two columns. In sixteen of the seventeen averages of averages, the responses II to VII are more like VIII than like I. If we use the five averages of averages where the sum of the two n's is 20 or more, giving equal weight to each of the five, we have 1.0 for the average number out of the 6 like I, and 2.2 for the average number out of the 6 like VIII. Using the five averages of averages where the sum of the two n's is 10 to 19 in the same way, we have 1.3 and 1.9. Using the remaining seven in the same way, we have 0.8 and 1.9. Completions II to VII are then unquestionably much more like Completion VIII than like Completion I. Experiment 96 thus lends no support to the doctrine that primacy is effective.

In general, the first connection shows no greater potency over the n connections immediately following it than the second connection does over the n connections immediately following it.

In general, also, the first connection shows no greater potency over those following it than the nth experience shows over those *preceding* it. On the contrary, in four of the six experiments there is much greater resemblance to what comes after than to what goes before. This excess is presumably due in general to

TABLE 137

THE INFLUENCE OF PRIMACY IN COMPLETING WORDS

Number of Letters		n	Av. No. in II–VII Like		Number of Letters		n	Av. No. in II–VII Like		Av. of the Two Avs. Like	
I	VIII		I	VIII	I	VIII		I	VIII	I	VIII
1	2	14	1.0	2.7	2	1	22	1.0	2.0	1.0	2.3
1	3	6	3.0	1.3	3	1	11	0.6	3.4	1.8	2.3
1	4	7	3.0	1.7	4	1	11	1.2	1.9	2.1	1.8
1	5	2	2.5	0.5	5	1	7	0.4	3.1	1.4	1.8
1	6	3	1.0	0.3	6	1	5	1.0	2.4	1.0	1.4
1	7	1	2.0	2.0	7	1	2	0.5	3.0	1.3	2.5
2	3	16	0.7	2.3	3	2	27	1.0	1.9	0.9	2.1
2	4	10	1.3	1.4	4	2	11	1.3	1.7	1.3	1.6
2	5	6	0.5	2.8	5	2	4	0.0	1.3	0.3	2.0
2	8	1	0.0	0.0	—	—	—	—	—	—	—
3	4	16	1.1	2.0	4	3	8	0.3	2.6	0.7	2.3
3	5	7	0.7	1.9	5	3	11	1.7	1.7	1.2	1.8
3	6	2	0.5	1.5	6	3	8	1.3	2.1	0.9	1.8
4	5	15	0.8	2.5	5	4	10	1.3	2.8	1.1	2.7
4	6	4	0.5	3.8	6	4	5	1.6	1.8	1.1	2.8
4	8	1	0.0	2.0	8	4	1	0.0	0.0	0.0	1.0
5	6	5	1.2	1.4	6	5	3	0.0	4.3	0.6	2.9
6	2	3	0.0	1.0	—	—	—	—	—	—	—
6	8	1	0.0	1.0	8	6	1	0.0	1.0	0.0	1.0
7	2	1	0.0	2.0	—	—					
7	4	3	1.7	1.7	—	—					
7	5	2	2.0	3.5	—	—					
8	3	1	0.0	4.0	—	—					
11	4	1	0.0	0.0	—	—					
11	9	1	2.0	4.0	—	—					

a tendency for the variability of responses to the same situation to become reduced.

We have not been able to find any clear evidence in the literature of association in support of the doctrine that the first connection made with a situation has, by being first, any advantage. The experiments of Calkins referred to by Pillsbury do not, as we interpret them, necessarily show that "the earlier one element enters into association with another, the more likely it is to be recalled with that than with any other with which it has been associated at a later period"; but rather that being first in a series of twelve paired-association tasks has an advantage over being in the middle of such a series. It seems probable that the factors advantage is not due to primacy in and of itself, but to the factors

which make both the beginning and the end of a series better remembered than the middle.

It seems probable that the facts, to explain which the doctrine of primacy was fabricated, are better explained by two corollaries of the general laws of learning. The first is that, other things being equal, the stronger a connection is, the oftener, and so the earlier, it will show itself. Being first does not make a connection stronger, but being strong makes a connection likely to be first. Let $S_1 \rightarrow R_1$, $S_1 \rightarrow R_2$, $S_1 \rightarrow R_3$, $S_1 \rightarrow R_4$ have strengths of 5, 2, 2, and 1, respectively. Then when S_1 occurs R_1 will be the first response five times as often as R_4 will, and also it will later occur five times as often.

The second is that when responses are connected with situations to which there are no preëxisting connections of more than infinitesimal strength (as in some cases of learning the names of strangers, the English equivalents of foreign words, and the like), the first experience raises the frequency from approximately 0 to 1, the second experience of the same connection raises it from 1 to 2, and so on. The *relative* strength of the connection with its competing infinitesimals is raised to 1 to 0 by the first experience, and only to 2 to 0 by the second experience. This is an effect of frequency caused by position and is allied to the facts of diminishing returns and overlearning. It is different from the alleged primacy effect. If, in such a case, we have two different responses, one in first position and the other in second position of occurrence, each will be raised to a relative strength of 1 to 0 compared with the infinitesimals; and the one in first place will be at no advantage over the one in second place.

These two simple facts, plus certain influences of novelty on attention, seem likely to be adequate to account for all that is true in the popular doctrine that first impressions are strongest.

The advantage for attention or memory of the first event of a series over later events in the series is, of course, a matter with which primacy, as defined here, has nothing to do.

We conclude, therefore, that the law of use or frequency does not need to be supplemented by any potency of primacy and that the general theory of connection-forming may be relieved from the incubus of the special theory that the response made by an individual to a situation the first time that he encounters it becomes, by virtue of that one experience, more strongly connected

with that situation—other things being equal—than does any response made to any single later occurrence of the situation by virtue of a like single experience.

We have shown that when the same situation is presented repeatedly and responded to, the response made first has no advantage as a result of its firstness over any other response made equally often, when the responses are such as the uninfluenced repertory of the individual provides. If the connection is controlled *ab extra*, the factors at work are somewhat different. Consequently we have made experiments upon the influence of primacy when the same situation is connected with various sequents by outside control, these sequents being equally often connected with it, and equally interesting and otherwise easy to remember in connection with it, and differing only in position.

Experiment 97

As a technic we use long series of word-number pairs such as were described in Chapter IV. In one such series, for example, the word *leafy* was connected first with *23*, then with *68*, still later with *82*, and last of all with *49*.

The series as a whole included about a hundred pairs, occurring from three to twenty-four times each, and required about thirty minutes for reading.

There were twelve pairs with such quadruple second terms, as follows (1, 2, 3, and 4 signifying the first, second, third, and fourth quarters of the reading):

leafy leafy leafy	*23*	occurring 4 times in	1
" " "	*68*	" " " "	2
" " "	*82*	" " " "	3
" " "	*49*	" " " "	4
group group group	*76*	" " " "	1
" " "	*53*	" " " "	2
" " "	*58*	" " " "	3
" " "	*93*	" " " "	4
album	*41, 41, 41*	occurring 4 times in	1
"	*74, 74, 74*	" " " "	2
"	*57, 57, 57*	" " " "	3
"	*92, 92, 92*	" " " "	4
bag	*69, 69, 69*	" " " "	1
"	*32, 32, 32*	" " " "	2
"	*83, 83, 83*	" " " "	3
"	*51, 51, 51*	" " " "	4

also also also	*17*	occurring	2	times	in	1
“ “ “	*26*	“	“	“	“	2
“ “ “	*27*	“	“	“	“	3
“ “ “	*63*	“	“	“	“	4
his his his	*31*	“	“	“	“	1
“ “ “	*84*	“	“	“	“	2
“ “ “	*41*	“	“	“	“	3
“ “ “	*55*	“	“	“	“	4
chaos	*18, 18, 18*	“	“	“	“	1
“	*87, 87, 87*	“	“	“	“	2
“	*33, 33, 33*	“	“	“	“	3
“	*62, 62, 62*	“	“	“	“	4
porter	*36, 36, 36*	“	“	“	“	1
“	*97, 97, 97*	“	“	“	“	2
“	*23, 23, 23*	“	“	“	“	3
“	*22, 22, 22*	“	“	“	“	4

legal legal legal occurred once each with *28, 89, 51,* and *67* in quarters 1, 2, 3 and 4, respectively.

mason mason mason occurred once each with *25, 29, 94,* and *47* in quarters 1 to 4, respectively.

alcove occurred once each with *34, 34, 34* and *86, 86, 86,* and *64, 64, 64,* and *46, 46, 46* in quarters 1 to 4, respectively.

rainbow occurred once each with *27, 27, 27* and *48, 48, 48* and *80, 80, 80* and *53, 53, 53* in quarters 1 to 4, respectively.

There were also six pairs each with twenty-four occurrences (*cherry 36, soft 53,* and *hasten 43, answer 63, ponder 73* and *favor 81*) used to compare two ways of distributing practice, ten pairs (like *dinner 26, insane 84, collect 91* and *borax 32*) used to compare impressive with unimpressive first terms; eight pairs with six occurrences each used to compare six occurrences in sequence with six occurrences scattered, and many other pairs used to fill out the series.

The subjects in some groups were instructed before the reading to relax and be comfortable and be uniformly just attentive enough to hear the words and numbers. In other groups they were instructed to attend uniformly and about as closely as they would to a class lecture. In all cases the instructions were prefaced by "I shall read a long series of pairs of words and numbers like *bread 29, butter 81, day 46.* Sometimes I shall say the word three times like this: *bread bread bread 29.* Sometimes I shall say the number three times like this: *butter 81, 81, 81.* The number will always be a two-figure number, from 10 to 99." At the end of the reading the subjects wrote numbers on the test sheet shown

below (Group 1, 2A, 2I), or wrote numbers as the experimenter read the words (Groups 3A and 3I). In the latter case they were instructed to write as many of the different numbers that came after a word as they could. In the former case less than 2 percent, and in the latter case about 5½ percent, of the records for the words that had four numbers as sequents were filled out with more than one number. In the case of Groups 3A and 3I, the subjects were also told that any given word might or might not be followed always by the same number and that at the end of the reading they would be tested in respect of what number or numbers followed the word. In the other groups nothing was said about a test until after the reading.

The totals correct for the four positions, in order, are:

Pairs occurring 4 times in each quarter	114,	65,	51,	97
" " 2 " " " "	55	32	39	39
" " 1 time " " "	33	24	24	17
All	202	121	114	153

The number first connected with a word under the conditions of this experiment is best remembered.

The causes for this are apparently that, when the word occurs in the second quarter with its second number, those who already know its first number are reminded of that by the contrast and think not only of the new *68* but also that it differs from the old *23*. They thus add frequency in the form of recall from within to the first appearing sequent of a word. There is also the chance for interference from both sides for the numbers in second and third position, but from only one side for those in first and last.

We may get further information about these causes from Experiment 98, in which certain words were followed by six or nine different numbers.

Experiment 98

A series of word-number pairs of the sort hitherto described was constructed containing 112 pairs. Among them were pairs in which the same word was followed by different numbers as follows:

2 each, with number repeated 3 times, of

however	47	55	85	72	16	45
if	23	82	65			
sequel	67	52	96	18	83	51
table	20	60	35	31	32	16
this	11	68	15	83	44	60

2 each, with both word and number repeated 3 times, of

at		73	45	53	16	32	84			
but		49	42	89						
consequently		74	69	12	46	78	17			
derive		78	22	34	21	94	27			
paper		38	41	80	42	96	31			
England	1 each of	61	95	75	13	31	77			
France	"	14	30	49	17	33	40			
garlic	"	89	76	19	50	22	33			
Germany	"	88	30	99	19	15	48			
home	"	73	11	18	20	80	63			
Italy	"	43	40	11	18	77	99			
money	"	32	29	15	89	28	87			
stink	"	56	24	90	75	38	91			
melon	3 each of	30	58	83	47	63	80	95	39	21
plant	"	69	61	25	96	24	88	19	44	91
rebel	"	59	82	61	20	64	85	97	40	95
shocking	"	23	86	75	31	38	40	93	43	84
balance	4 each of	98	46	84	19	12	45			
deduce	"	29	15	71	33	68	54			
token	"	35	91	17	41	26	75			
willing	"	13	44	89	28	62	53			
cancer	2 each of	78	34	16	98	74	38			
cigar	"	51	62	64	55	12	39			
debt	"	64	97	55	67	74	17			
lunch	"	13	86	40	97	76	99			
nevertheless	"	25	54	70	29	35	26			
practice	"	35	58	32	66	80	34			
solvent	"	58	16	95	48	39	68			
with	"	42	24	66	72	51	67			
when	"	71	66	53						

2 each, with word repeated three times, of

and	87	21	59			
as	54	43	41	90	28	52
moreover	71	60	94	77	29	18
vacant	93	50	56	90	15	78
window	52	87	91	33	59	17

These pairs occurred in the order shown above in successive ninths, sixths, or thirds of the series. At least twenty occurrences intervened between any two occurrences of the same pair except for the immediate repetitions described above. At the beginning

of the series there were ten occurrences of words not in the above list, and at the end of the series there were ninety such. The sixty-eight pairs used as fillers included four pairs of opposites to be used in a study of interference, and seven pairs suggesting reasonable associations such as *aged 99*, *five 55*, and *hexagon 66*.

This series was read to a group of adult students half of whom were instructed to attend about as they would ordinarily to a lecture or sermon, the other half being instructed to relax and pay only as much attention as would enable them to take oath that they had heard each word and number. All were informed that uniformity of attention throughout was the essential desideratum.

Half of the group had Test Form A and half, Test Form B.

Form A

Write after each word the number or numbers which came just after it in the reading, if you remember what they were. Go through the list, first writing any that you are fairly sure about. Then go through it a second time, guessing at the others. But if you have no idea whatever as to what number or numbers followed the word draw a dash after it.

aged
and
balance
black
but
consequently
debt
France
garlic
Germany
home
hot
lip
long
lunch
moreover
plant
practice
rich
sequel
shocking
solvent
table
this
token
turns
with

Form B

Write after each word the number or numbers which came just after it in the reading, if you remember what they were. Go through the list, first writing any that you are fairly sure about. Then go through it a second time, guessing at the others. But if you have no idea whatever as to what number or numbers followed the word draw a dash after it.

as
at
cancer
cigar
cold
deduce
derive
England
hexagon
however
if
Italy
melon
money
nevertheless
paper
poor
quarter
rebel
short
solve
stink
vacant
when
white
willing
window

The results in general support the view that mere firstness as such, irrespective of extra repetitions aroused by contrast and of less interference from the alternative responses, and of greater attentiveness and zeal, does little or nothing.* When the word occurs only once with each of six numbers, so that the number attached to it at its first appearance is known with little or no surety, the number of correct responses in the test was 17 in first position, an average of 16 for positions 2 to 5 (12, 32, 12, 8), and 15 in its final position. In a very carefully conducted experiment

* Although the subjects were cautioned to endeavor to maintain even attentiveness throughout, some of them reported that they paid more attention to the early part of the reading than to the late.

with ten subjects where attention was reported as not appreciably altered, the corresponding numbers were 5, average of 5+ (6, 7, 4, and 4), and 8. When there are two or more occurrences, the numbers correct for the six positions were 84, 38, 54, 43, 49, and 53. In the more carefully controlled experiments with ten subjects, the corresponding numbers were 16, 20, 16, 13, 8, and 15. For the words followed by nine different numbers the numbers correct are 11, 9, 10, 4, 12, 7, 6, 2, and 8 for both experiments combined.

This does not exhaust the possible influences of primacy. In some circumstances, by controlling matters so that S evokes A the first time, we may reduce greatly the probability of its evoking anything other than A the second time; and the second occurrence of S⟶A may further reduce the probability of S⟶not-A. Thus it may often be pedagogically very profitable to pay special heed to the first response to a situation, so as to reduce the frequency of errors. With well arranged occurrences there may never be *any* wrong responses. What we have shown nowise contradicts this, but merely affirms that if *p right responses and q wrong responses are to occur*, the latter will do little or no more harm by occurring early than by occurring late.

Recency

Since the right connection often is the one that puts an end to the situation for the time being, it often is the most recent connection from the point of view of the next occurrence of the situation. So in a rat running a maze, or in a cat obtaining entrance to or exit from a puzzle-box, or in a dog responding in a multiple choice situation, the right connections will, on the average be the more recent. Other things being equal, the connection which has operated most recently will be the strongest in the sense of the least weakened by disuse. Therefore some fraction of adaptive learning may be explained as a consequence of recency. This fraction is, however, probably extremely small, so small as to be practically negligible. The difference in recency between the selected and the discarded connections is rarely great. It varies roughly from the difference between 9 and 10 to the difference between 999 and 1000, according as the situation recurs very soon or is delayed for a day or more. Learning in the latter cases is not demonstrably less real, or even less rapid than in the former. Moreover, in certain experiments of the multiple choice type so

arranged that the response, right or wrong, alike puts an end to the situation for the time being and that the rights are not on the average more recent, learning occurs with no demonstrable handicap.

We may then disregard recency in explanations of learning, assigning to it only a very minor, auxiliary rôle.

The principle of recency in general needs classification and systematization. It arose as a statement of the obvious fact of forgetting; that, other things being equal, a situation is more likely to evoke a response connected with it a short time ago than one connected with it a long time ago. This is not the whole truth. If the *time ago* is very short, the connection, though strong, may be unready to act, there being a refractory period.* If the ratio of recency of B to recency of A does not differ much from 1.00 and if S→A and S→B are components of a series of mental operations which belong together as part of a certain total, such as a game, an experiment, a book read, a topic studied, or the like, the effect of the difference in recency may not be observable.

On the other hand, the most emphatic case of potency of recency was not considered by the general principle. This is the case of the continuance of a connection, as a sort of memory after-image, for a second or so. This enables us to hold it, repeat it, and so fix it, provided the response is what we have called "available." This difference between 0 seconds and 1.0 seconds is, of course, probably physiologically very different from the difference between, say, 24 hours and 24 days and was quite properly not included in the historic doctrine of recency.

The technic of our experiments with long series of pairs is useful for a study of differences in recency ratios from 2 to 1 to 10 to 1 with total intervals of two hours or less. They enable us to measure the influence of recency in two ways. First, we may attach two or more different second members to the same first member, attaching one to it much later in the series and so much more recently from the point of view of the test. Second, we may use pairs which in general represent connections equally easy to form, putting the occurrences of one such pair much later in the series and so much nearer to the time of the test than the other. We have done only the former.

* Dodge has suggested that the influence of this may be much more widespread than has commonly been supposed.

We have used four positions covering the first, second, third, and fourth quarters of a 30-minute series.* Since the test time is approximately one-sixth of the series time and follows it directly, this gives recency ratios whose numerators and denominators are approximately .87½ + .08½, .62½ + .08½, .37½ + .08½ and .12½ + .08½, the extreme case being $\frac{.96}{.21}$ or about 4½ to 1.

In a two-hour series, since the test time is then only about one-twelfth of the series time, the ratios will have more spread, the extreme being about $\frac{.91}{.16}$ or nearly 6 to 1.

The results have already been stated in the discussion of primacy. 202, 121, 114, and 153 were the total correct in the four positions. Occurrence in the last position of four causes a stronger connection than does occurrence in position 2 or 3, but position 3 is not more favorable than position 2. Position 4 is not so favorable as position 1. The connections made in position 4 are without interference on one side and probably derive most of their advantage from that fact rather than from pure recency.

In the experiment in which the same first term was connected with six or nine different second terms in the corresponding sixths or ninths of the series, the totals correct were as stated on pages 567 f., but it is doubtful whether they are worth very serious attention, because of the drop in attention on the part of some subjects as the reading progressed. A reasonable interpretation of them is that the superiority of the last position to earlier positions would have been somewhat greater than the figures show, but that it would have been due to less interference rather than to the slight difference in recency.

* In all cases the series closes with about 100 pairs not involved in the test, so that the results are uninfluenced by anything resembling the memory-after-image effect.

APPENDIX VIII

Estimates of the Influence of Rewards and Punishments in Various Experiments with Animal Learning

We report first the results of the method of analysis described in Chapter XI, or as near an approach to it as permits fairly full utilization of the data. Its general result is an estimate of a rise of .32 over chance for one rewarded connection, .35 over chance for two rewarded connections, .11 over chance for one punished connection, and .09 over chance for two punished connections. These estimates should not be taken as at all authoritative. For we cannot be sure that the initial tendencies of the animals concerned to respond to the Yerkes Multiple-Choice apparatus are due to chance alone. Also the material is scanty, and the different animals differ widely.

We have used as the first set of data the rewarded and punished responses of the crows studied by Coburn and Yerkes ['15] with the multiple choice apparatus. The reward for entering the right compartment was food. The punishment for entering the wrong compartment was confinement therein, usually for thirty seconds.

When there were three compartments to choose from, the facts for a right *versus* a wrong in trial 1 or 2 or 3 (but not before) are as follows: A right was followed by a right eighteen times out of twenty-one, or .52 more than the chance expectation. A wrong was followed by a response other than that same wrong twenty times out of twenty-three or .20 more than the chance expectation. The facts for two rights *versus* two wrongs in trials 1 and 2 or 1 and 3 (but not in 2) or 2 and 3 (but not in 1) are as follows: A right was followed by a right twelve times out of sixteen, or .42 more than chance. A wrong was followed by a response other than that same wrong six times out of seven or .19 more than chance.

When there were five compartments to choose from, the facts for one right *versus* one wrong in the same positions as regards trials were: One right is followed by a right eight times out

of twelve or .47 more than chance. One wrong is followed by a response other than that wrong fourteen times out of seventeen or just a little more than chance (.02). Two rights (in trials 1 + 2, 1 + 3, 2 + 3, or 2 + 4) are followed by a right seven times out of nine or .57 more than chance. Two of the same wrong in these trials are followed by some response other than that same wrong five times out of six or just a little more than chance (.03).

The facts for four and six compartments are scanty and we combine them. One right has a following right eight times out of ten. One wrong is followed by some response other than that same wrong thirteen out of fifteen times. Calling the expectations by chance .20 and .80, the right shows an excess of .60 and the wrong an excess of .07. For two rights and two wrongs the facts are one out of five and one out of three, respectively.

Combining the facts for four, five and six choices, we have strengthenings of +.53 and +.37 for one and two rights, and strengthenings of +.04 and —.13 for one and two wrongs.

The very scanty records for the nine-compartment experiment show one right followed by one right out of 1, and one wrong followed by other than that same wrong in three out of four. This gives .89 over a chance for the right and .14 under chance for the wrong. For two rights, we have also one right sequent out of 1, or .89 over chance.

For Sadovinkova's canaries we have the following:

When there were three compartments to choose from, a right in trial 1 or 2 or 3 (but not before) was followed by a right seven times out of eight, or in .54 more than chance. A wrong in trial 1 or 2 or 3 (but not before) was followed by other than the same wrong twice out of three or 0 more than chance. Two rights in trials 1 and 2, or in 1 and 3 but not in 2, were followed by a right five times out of eight, or .29 more than chance. Two comparable cases of the same wrong were followed by other than that wrong in the only case where they occurred in the first three trials, or .33 more than chance.

We combine the data for experiments where there were four, five, or six compartments to choose from. A right in trial 1 or 2 or 3 (but not before) was followed by a right ten times out of twenty, or .28 more than chance (counting this as .22 since there were eight, ten, and two responses for four-, five-, and six-compartment tests, respectively). A comparable wrong was followed by other

than that same wrong eighteen times out of twenty-one, or .09 more than chance. (There were ten, seven, and four responses for the four-, five-, and six-compartment tests.) Two rights in trials 1 and 2 or in 1 and 3 but not in 2, were followed by a right seven times out of thirteen, or about .34 more than chance. Two comparable wrongs were followed by other than that same wrong three times out of three or .25 more than chance (all three occurrences were in the four-compartment test).

In the nine-compartment experiment one right in trial 1 or 2 or 3 (but not before) showed a strengthening of .29 over chance (two out of five); one comparable wrong showed a strengthening of other than that one wrong of .01 below chance (fifteen out of seventeen). For two rights and two wrongs the sequents are one right out of two, and some other than that same wrong out of one, or .39 over chance and .89 under chance.

The general drift for the crows and the canaries is to show a

TABLE 138

THE INFLUENCE OF REWARD AND PUNISHMENT OF ONE OR TWO OF THE FIRST THREE RESPONSES UPON THE SEQUENT CONNECTION: CROWS AND CANARIES

	Number of Choices	Sequent R	Sequent W	% R	Strength Above Chance
One right in trial 1 or 2 or 3 but not before	3	25	4	86	.53
"	4 and 6	10	10	50	.30
"	5	16	6	73	.53
"	9	3	3	50	.39
Two rights in trials 1 and 2, or 1 and 3 but not 2, or 2 and 3 but not 1	3	17	12	59	.26
"	4 and 6	3	6	33	.13
"	5	12	3	80	.60
"	9	2	1	67	.56
One wrong in trial 1 or 2 or 3, but not before	3	4	22	84	.17
"	4 and 6	6	61	91	.11
"	5	4	40	91	.11
"	9	2	15	88	−.01
Two of the same wrong in trials 1 and 2, or 1 and 3 but not 2, or 2 and 3 but not 1	3	1	7	88	.21
"	4 and 6	3	7	70	−.10
"	5	2	12	86	.06
"	9	1	0	0	−.89

pronounced strengthening over chance for the rewarded connections, and little or no strengthening over chance for other than the punished connection. This may be seen from Table 138 in which the results are combined for both groups.

From the records given by Yerkes and Coburn ['15] and Yerkes ['16] for pigs and monkeys, reported here in Tables 139, 140, 141, 142, and 143, we make computations just like those reported for Yerkes' crows and Sadovinkova's canaries. The response, as with the crows and canaries, was entering one of several compartments. The punishment for a wrong response was confinement for thirty seconds. The reward for a correct response was freedom and food. We show the results in Table 144. These records differ from those of the crows and canaries in showing much more frequent occurrences of something other than a punished connection as its sequent. The average strengthening over chance here (unweighted) is 0 for one reward and .32 for two. The average strengthening of other than the connection punished (also unweighted) is .15 for one and .13 for two.

If we combine all the strengthenings in Tables 138 and 144 to make an average, weighting each by the number of sequents which it represents, we have the following:

one rewarded, showing a strengthening of the rewarded of	.32
two rewarded, showing a strengthening of the rewarded of	.35
one punished, showing a strengthening of other than the punished of	.12
two punished, showing a strengthening of other than the punished of	.09

The method of study, the results of which we report next, was to compare, within the same sort of tasks, an animal (or animals) that had the most (or very many) right responses in the first sixteen, with an animal (or animals) that had the most (or very many) of some one wrong response (or of some two wrong responses) in the first sixteen and had few rights. Sometimes we have to go beyond sixteen responses to get any sharp contrast. Instances where the experimenter after a series of many wrong responses aided the animal to go through the right door to food so as to encourage him in later efforts were simply omitted from all counts. We have applied this method to the records of the monkeys and pigs of Tables 139 to 143.

Using the records given by Yerkes and Coburn ['15] and Yerkes ['16] for the two pigs and two monkeys in Problems 3R and 3L (first door at the right and first door at the left) with

TABLE 139

THE FIRST 24 RESPONSES OF MONKEYS SK AND SOB AND PIGS F AND M IN THE YERKES MULTIPLE-CHOICE APPARATUS

Problems 3 R and 3 L, using 3 and 4 doors. C = the correct door, 1 = the door next to it, 2 = the next door, 3 = the next door.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
												3 R Using 3 Doors													
1	Sk	1	C	1	2	1	2	C	C	1	2	C	C	1	2	C	1	2	C	C	C	C	C	C	C
2	Sob	2	C	2	C	C	2	1	2	C	1	2	2	C	1	2	C	C	2	C	1	2	C	C	2
3	F	1	2	C	1	C	2	C	2	C	1	2	C	2	C	C	C	2	C	1	C	C	1	C	C
4	M	C	1	C	C	C	C	2	C	1	2	C	1	C	1	C	C	C	1	C	1	C	C	C	C
												3 L Using 3 Doors													
5	Sk	2	C	2	1	C	2	1	2	C	2	1	C	2	1	C	2	1	C	2	1	C	2	1	C
6	Sob	1	1	2	1	1	C	1	1	1	C	1	C	1	C	2	1	C	C	2	1	C	1	C	2
7	F	2	C	2	1	C	2	1	C	2	1	2	C	C	2	1	C	C	C	C	1	2	C	C	2
8	M	1	C	1	C	1	C	2	1	C	2	1	C	1	2	C	2	C	2	C	2	C	1	C	C
												3 R Using 4 Doors													
9	Sk	C	1	C	C	3	C	C	3	C	2	3	C	C	3	1	C	C	C	C	C	C	C	C	C
10	Sob	2	3	C	2	1	3	1	1	C	2	3	1	3	3	C	3	C	3	2	3	3	C	3	1
11	F	2	1	2	C	2	C	C	C	C	C	2	C	2	C	2	C	C	C	C	C	C	C	C	2
12	M	C	C	2	C	3	C	3	1	2	3	C	1	C	2	C	2	C	2	C	C	C	C	C	C
												3 L Using 4 Doors													
13	Sk	2	1	3	2	3	C	3	2	1	C	3	1	3	2	1	3	1	3	2	1	3	2	3	1
14	Sob	C	1	C	2	1	C	2	C	2	3	2	C	2	3	2	1	C	C	3	2	C	C	C	C
15	F	C	2	C	C	1	C	1	C	C	C	C	C	C	C	3	1	C	C	C	C	C	C	C	C
16	M	3	2	1	C	C	1	3	C	1	C	3	C	1	3	C	2	C	3	C	C	1	3	C	1

TABLE 140

The first 24 responses of monkeys Sk and Sob and pigs F and M in the Yerkes multiple-choice apparatus

Problems 3 R and 3 L, using 5, 6, and 7 doors. C = the correct door, 1 = the door next to it, 2 = the next door, and so on.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
												3 R Using 5 Doors													
17	Sk	C	C	C	C	C	C	C	C	4	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
18	Sob	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
19	F	C	1	C	C	4	1	3	4	C	2	C	2	4	3	1	C	2	4	2	C	1	C	1	C
20	M	1	2	C	C	2	C	C	C	C	C	2	C	1	C	C	3	C	C	C	1	C	C	C	C
												3 L Using 5 Doors													
21	Sk	3	4	3	2	1	2	C	4	3	2	4	3	1	4	4	3	2	4	2	1	C	4	3	2
22	Sob	3	4	3	4	4	4	3	4	3	3	4	3	3	1	4	4	3	4	3	4	4	4	3	3
23	F	C	3	1	2	C	4	3	2	1	C	4	C	C	4	C	1	3	4	C	4	C	4	1	4
24	M	3	2	C	3	4	1	C	4	3	C	4	2	4	3	C	3	4	2	3	C	4	2	C	3
												3 R Using 6 Doors													
25	Sk	1	3	C	1	3	4	2	C	4	1	1	C	3	4	C	C	C	4	5	C	5	1	C	C
26	Sob	3	5	4	5	2	2	4	5	1	2	C	3	5	2	3	C	3	C	4	1	3	C	4	5
27	F	C	1	2	3	C	3	C	3	C	3	2	C	C	2	C	C	3	1	C	3	C	2	C	3
28	M	5	3	1	1	C	1	2	3	C	3	4	C	1	2	3	1	C	1	4	5	2	C	4	1
												3 L Using 6 Doors													
29	Sk	5	4	3	5	2	1	5	3	2	5	4	3	5	4	3	5	4	2	1	4	5	1	4	5
30	Sob	3	3	2	4	3	4	3	1	C	2	3	1	4	3	4	5	3	1	2	2	5	4	3	1
31	F	2	4	3	5	4	2	1	4	3	2	5	4	3	C	4	5	3	1	2	C	1	C	3	1
32	M	4	3	2	1	5	4	2	3	1	4	2	4	C	1	C	4	3	2	1	5	4	C	4	3
												3 R Using 7 Doors													
33	Sk	1	2	3	4	5	4	1	2	3	4	1	2	3	1	6	2	3	5	6	C	1	C	C	C
34	Sob	6	1	C	1	3	C	C	C	C	C	C	6	C	C	C	C	C	C	6	C	C	C	C	C
35	F	C	5	2	1	C	2	1	2	3	C	3	4	1	2	C	1	3	6	1	5	C	2	1	C
36	M	4	2	1	C	1	2	C	1	2	4	5	1	C	1	C	C	3	6	1	2	C	2	C	C
												3 L Using 7 Doors													
37	Sk	6	5	4	3	1	C	5	4	3	2	1	C	6	5	4	3	2	1	C	6	5	4	3	2
38	Sob	6	5	4	6	5	4	3	6	5	4	6	5	5	4	C	6	5	4	6	4	3	2	1	C
39	F	5	4	3	4	2	5	1	4	6	2	5	3	4	C	5	4	3	C	6	4	C	5	4	C
40	M	5	4	3	5	4	4	C	C	5	4	6	5	3	C	4	3	6	5	4	C	6	4	3	5

TABLE 141

THE FIRST 24 (OR 56) RESPONSES OF MONKEYS SK AND SOB AND PIGS F AND M IN THE YERKES MULTIPLE-CHOICE APPARATUS

Problems 2 and 4, using 3 and 4 doors. C = the correct door. 1 and 2 = the doors on one side of the correct door, in order. + 1 = the door on the other side of the correct door.

Record	Problem	Choices		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
41	2	3	Sk	1	1	+1	1	C	+1	1	C	+1	1	C	C	C	+1	C	C	+1	+1	+1	C	C	+1	+1	+1
42	2	3	Sob	1	1	+1	1	1	+1	1	+1	1	+1	1	+1	+1	1	+1	1	+1	+1	+1	+1	1	1	1	1
43	2	3	F	1	C	+1	1	+1	+1	+1	1	C	+1	1	C	1	C	C	1	C	1	C	1	+1	C	+1	+1
44	2	3	M	1	1	1	1	1	1	+1	1	C	1	1	C	C	+1	1	+1	1	+1	C	C	1	+1	C	C
45	4	3	Sob	1	+1	1	+1	C	+1	1	+1	1	1	+1	1	+1	1	1	+1	1	+1	C	+1	1	1	+1	1
46	4	3	F	1	C	1	+1	1	C	1	+1	C	1	+1	C	+1	C	+1	C	C	C	1	+1	+1	C	1	C
47	4	3	M	1	+1	1	+1	C	1	+1	1	+1	1	C	1	+1	C	C	1	+1	C	C	C	C	1	C	C
48	2	4	Sk	2	1	1	2	+1	2	1	2	1	2	C	C	C	1	+1	+1	2	1	+1	1	2	1	+1	2
49	2	4	Sob	2	1	+1	2	2	+1	2	2	+1	1	+1	C	+1	2	+1	2	+1	2	+1	1	2	+1	2	+1
50	2	4	F	2	2	2	2	2	2	+1	+1	2	+1	+1	C	2	C	+1	2	+1	+1	C	2	+1	+1	+1	C
51	2	4	M	2	+1	2	C	+1	2	+1	2	+1	1	+1	C	+1	2	+1	1	2	+1	2	1	+1	2	C	+1

Continuation of Records 48 to 51

25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
+1	+1	+1	+1	C	+1	+1	C	+1	C	+1	C	+1	C	+1	+1	C	+1	C	+1	C	+1	+1	C	C	+1	C	+1	C	+1	C	+1
2	C	+1	+1	+1	+1	+1	+1	+1	1	+1	+1	+1	+1	+1	+1	+1	+1	+1	C	+1	C	+1	1	+1	1	2	C	+1	2	1	+1
2	+1	2	+1	+1	1	C	+1	C	+1	1	C	+1	C	+1	1	+1	1	+1	C	+1	1	+1	2	C	+1	C	C	C	+1	2	C
2	1	+1	C	+1	2	+1	1	2	+1	C	C	1	+1	2	+1	C	2	+1	1	C	+1	1	2	+1	1	C	C	+1	2	C	C

TABLE 142

THE FIRST 56 RESPONSES OF MONKEYS SK AND SOB AND PIGS F AND M IN THE YERKES MULTIPLE-CHOICE APPARATUS

Problems 2 and 4, using 5 to 9 doors. C = the correct door. 1, 2, 3, etc., = doors on one side of the correct door, in order. + 1, + 2, + 3, etc., = doors on the other side of the correct door, in order

Record	Problem	Choices		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
52	2	5	Sk	3	3	C	2	1	1	1	C	1	C	1	+1	1	+1	C	2	1	C	C	1	+1	C	1	+1
53	2	5	Sob	2	+1	1	C	+1	+1	3	+1	+1	+1	3	+1	3	+1	1	+1	C	3	+1	C	1	2	3	+1
54	2	5	F	3	+1	3	C	+1	3	2	1	+1	2	1	C	1	+1	3	C	3	C	2	+1	C	+1	C	1
55	2	5	M	3	3	C	1	3	C	+1	C	C	+1	C	+1	+1	C	+1	3	2	3	C	+1	3	1	3	C
56	4	5	Sob	2	+2	2	2	2	+2	2	1	2	+1	+2	2	+2	2	C	+2	1	2	+2	1	+2	1	2	+2
57	4	5	F	2	+2	2	+2	1	2	+2	+2	2	+2	+1	+2	2	+2	+1	1	C	2	+2	2	+2	C	2	+1
58	4	5	M	2	+2	2	+2	C	2	+2	+1	+2	2	+2	2	+1	2	+2	1	+1	2	+2	1	+2	C	2	+2
59	2	6	Sk	4	3	4	3	4	1	4	3	4	1	C	1	+1	4	1	4	4	3	+1	4	+1	C	2	1
60	2	6	Sob	3	4	+1	4	+1	+1	+1	1	4	+1	1	+1	4	+1	4	+1	4	4	4	2	4	+1	4	4
61	2	6	F	+1	2	+1	3	4	+1	3	+1	+1	2	C	+1	4	C	+1	C	+1	2	1	+1	2	+1	4	1
62	2	6	M	4	C	+1	C	+1	1	4	+1	3	1	+1	2	C	+1	C	+1	C	+1	C	+1	C	+1	4	C
63	4	7	Sob	3	+3	3	1	3	+3	3	+3	3	+3	+3	3	2	3	3	+3	3	C	3	2	+3	3	+3	1
64	4	7	F	3	+3	C	3	+3	1	+3	3	+2	+3	3	C	3	+3	1	+2	3	+1	1	+3	2	3	+2	+1
65	4	7	M	3	+3	3	+3	C	3	+3	1	+2	3	+3	C	3	+2	+1	+3	2	1	+1	3	+3	C	+2	3
66	2	9	Sk	4	7	C	4	2	3	2	5	C	3	C	2	3	4	5	6	7	3	C	3	4	5	5	2
67	2	9	Sob	+1	7	C	+1	3	3	+1	1	7	2	2	2	3	2	+1	4	2	7	2	+1	2	C	C	1
68	2	9	F	2	4	C	6	1	4	C	1	7	4	C	2	C	1	+1	2	1	3	C	1	+1	5	2	6
69	2	9	M	7	3	C	2	+1	C	C	+1	2	C	1	2	4	5	6	7	+1	C	1	C	C	C	C	1
70	4	9	Sob	4	+4	2	4	+4	3	+4	2	+4	4	4	1	2	3	+3	+4	4	+4	4	+4	4	1	+1	2
71	4	9	F	4	+4	C	C	4	+3	C	C	3	+2	+4	4	1	3	+4	C	4	+4	+2	2	C	+1	+2	+4
72	4	9	M	4	+4	3	+3	+1	C	3	+1	2	+4	4	1	C	4	2	3	1	4	+4	+2	C	3	+3	+1

TABLE 142 (*Continued*)

	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Sk	1	2	3	1	2	1	2	+1	2	3	1	3	C	1	+1	C
Sob	C	1	3	+1	2	3	+1	C	2	3	+1	1	2	3	+1	C
F	+1	2	+1	1	3	+1	C	+1	C	+1	1	2	3	+1	2	C
M	+1	C	+1	C	+1	C	+1	C	C	3	+1	C	+1	C	+1	C
Sob	1	2	1	2	2	+2	2	2	C	2	+2	1	1	+2	2	+2
F	+2	2	+2	1	+2	+1	C	2	+1	+2	1	2	+2	1	+1	C
M	+1	C	2	+1	1	+2	C	1	+1	2	C	1	2	+1	+2	C
Sk	3	3	2	2	1	1	C	+1	+1	3	2	1	+1	+1	1	3
Sob	4	+1	1	4	+1	4	2	+1	4	+1	4	+1	3	4	+1	4
F	C	C	C	+1	1	4	2	+1	1	3	+1	4	C	C	+1	C
M	+1	+1	2	3	1	2	C	+1	C	C	+1	C	2	+1	C	+1
Sob	+3	C	3	+3	3	+2	2	3	3	1	3	2	3	+3	C	3
F	2	+3	+1	+2	C	3	+2	+3	C	3	+2	C	1	+2	3	+3
M	1	+3	C	+1	3	C	1	3	+2	C	+1	3	+2	C	3	C
Sk	C	1	2	4	1	2	C	2	1	2	4	5	6	2	5	1
Sob	4	6	7	+1	C	3	+1	C	2	3	6	5	7	C	C	1
F	C	1	C	1	C	C	C	1	C	1	1	4	C	5	1	2
M	2	4	C	C	1	2	3	4	5	C	C	C	C	1	2	C
Sob	3	+2	C	3	+2	C	3	+2	+1	1	3	+2	2	+3	+4	+1
F	2	3	C	C	3	+1	1	C	+1	+2	3	+4	3	1	+1	C
M	1	3	C	3	C	3	+1	4	1	2	3	C	2	+4	C	3

	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Sk	C	C	1	C	2	C	C	1	C	1	+1	C	+1	C	C	+1
Sob	2	3	+1	C	+1	C	1	2	3	C	2	3	2	C	+1	C
F	C	C	+1	C	+1	3	2	C	+1	1	+1	1	C	+1	C	+1
M	3	3	+1	C	+1	C	+1	C	+1	C	1	3	+1	C	3	+1
Sob	2	1	2	C	+2	2	1	2	+2	1	+1	2	C	2	1	2
F	C	2	1	+1	+2	2	1	+2	+1	1	+2	2	C	2	+1	C
M	1	2	+1	+2	C	2	1	+1	2	C	+2	+1	C	2	+1	+2
Sk	1	+1	C	C	1	C	2	4	+1	C	C	C	2	3	+1	C
Sob	4	+1	C	+1	+1	1	+1	+1	C	+1	4	3	+1	C	+1	2
F	+1	3	C	C	+1	C	4	+1	3	+1	C	2	C	+1	C	C
M	C	1	2	C	+1	C	4	2	3	C	C	C	1	2	3	4
Sob	+1	2	+2	2	3	1	+2	3	+1	3	+3	C	1	2	+1	2
F	+1	C	1	C	C	+2	1	C	C	+1	3	+2	+3	+1	+2	2
M	C	+2	3	+2	+1	C	3	+3	C	3	C	+1	2	3	+2	+1
Sk	C	C	C	1	C	+1	2	4	1	C	C	2	1	C	2	C
Sob	2	3	+1	C	+1	C	C	1	2	3	7	C	1	2	3	6
F	5	3	C	C	C	C	1	C	C	C	C	1	1	1	C	C
M	C	C	C	C	C	C	C	1	2	4	5	6	+1	C	C	C
Sob	+1	1	3	+2	1	+3	+1	C	1	+2	2	+2	1	+1	4	1
F	3	1	+1	+2	C	3	1	C	4	1	2	C	C	+1	C	2
M	2	+2	+2	+3	3	2	+3	1	+1	+2	3	C	C	C	+2	2

TABLE 143

THE FIRST 24 RESPONSES OF SK, SOB, ORA, F, AND M IN PROBLEM 1 OF THE YERKES MULTIPLE-CHOICE APPARATUS

Record	Problem	Choices		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
73	1	3	Sk	C	2	C	1	2	C	1	2	2	2	1	C	C	1	2	2	C	2	1	C	C	2	2	C
74	1	3	Sob	C	2	C	C	2	C	2	C	C	C	C	C	2	C	2	2	C	C	2	C	C	C	C	C
75	1	3	Ora	2	C	C	1	C	C	C	2	C	2	1	C	C	C	C	C	2	C	2	1	C	C	C	C
76	1	3	F	2	C	C	1	2	C	2	C	C	2	C	C	C	C	C	C	C	1	C	C	C	C	C	C
77	1	3	M	1	2	C	2	C	2	1	C	1	C	2	C	1	2	C	2	C	1	2	C	1	C	C	C
78	1	5	Sk	3	4	C	C	2	C	4	C	C	2	C	C	1	4	C	2	4	C	3	4	C	1	2	4
79	1	5	Sob	C	C	C	4	C	1	C	4	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
80	1	5	Ora	1	C	C	1	C	C	1	C	C	1	C	C	1	C	C	1	C	C	1	C	C	1	C	C
81	1	5	F	3	C	C	C	4	1	C	C	C	C	1	C	2	C	C	C	C	C	C	C	C	C	C	1
82	1	5	M	4	3	C	C	C	4	2	C	C	2	1	C	3	C	4	2	C	C	C	C	C	C	C	C

TABLE 144

THE INFLUENCE OF REWARD AND PUNISHMENT OF ONE OR TWO OF THE FIRST THREE RESPONSES UPON THE SEQUENT CONNECTION. MONKEYS AND PIGS

	Number of Choices	Sequent R	Sequent W	% R	Strength Above Chance
One right in trial 1 or 2 or 3 but not before:	3	2	12	14	−.19
	4	1	4	20	−.05
	5	9	5	64	+.44
	6	0	3	0	−.17
	7	0	3	0	−.14
	9	1	4	20	+.09
Two rights in trial 1 and 2, 1 and 3, or 2 and 3, but not before:	3	1	3	25	−.08
	4	2	1	67	+.42
	5	5	1	83	+.63
	6	0	0		—
	7	0	0		—
	9	0	0		—
		Same W	Other W	% Other W	
One wrong in trial 1 or 2 or 3 but not before:	3	4	18	82	.15
	4	2	20	91	.16
	5	1	26	96	.16
	6	2	28	93	.10
	7	1	27	96	.10
	9	0	16	100	.11
Two of the same wrong in trials 1 and 2, 1 and 3, or 2 and 3, but not before:	3	1	11	92	.25
	4	1	3	75	.00
	5	1	7	88	.08
	6	0	3	100	.17
	7	0	11	100	.14
	9	0	0	—	—

three or four doors in use, we have the records of Table 139 for the first twenty-four responses for each animal. We compare records 3 and 4 in which there were eight and ten rewarded responses out of the first sixteen with records 5 and 6 in which there were four and ten of the punished responses of going to the middle door of the three. The two records with eight and ten rewarded responses out of thirty-two show 69 percent of right responses in responses 17 to 24, or a strengthening of .36 over what mere chance choice would give, or .19 above the prob-

ability shown in the first four responses. The two records with four and ten of the punished response of going to the middle door of the three show 56 percent responses other than it in responses 17 to 24, or .11 less than mere chance choice would give, or .06 above the probability shown by the first four responses.

We also compare records 9, 11, and 15 in which there were nine, nine, and eleven rewarded responses out of the first sixteen with records 10 and 13 in which there were six and six of the punished response of going to the door at the wrong end. The former show eight, eight, and seven rights in responses 17 to 24, or .71 over what chance would give, or .52 above the probability shown in the first four responses. The latter shows in responses 17 to 24, four and five responses other than the one wrong in question or .19 less than what chance would give, or .19 below the probability shown in the first four responses.

The strengthening due to the eight, ten, nine, eleven, and nine rights out of sixteen may also be measured by the results on the seventeenth response. In four out of five cases it was the right response, showing a strengthening of about .50 over mere chance. Responses 17 and 18 were both right in three out of five cases, showing a strengthening of about .50 over mere chance. Responses 17, 18, and 19 were all three right in three out of five cases, showing such a strengthening of about .57. Responses 17, 18, 19, and 20 were all four right in three out of five cases, showing such a strengthening of .50. If we use the probability according to responses 1 to 4 those respective strengthenings are .25, .45, .60, and .60.

The lack of strengthening of other than the one wrong due to the four, ten, six, and six out of sixteen, each for that particular wrong, measured by the results on responses 17; 17 and 18; 17, 18, and 19; and 17, 18, 19, and 20 is as follows: The responses were other than that one wrong in three cases out of four, one out of four, one out of four, and 0 out of four, respectively, or about .09 over chance, .25 under chance, .10 under chance, and .25 under chance. If we use the probability according to responses 1 to 4, these become .12½ over, .08 under, .12½ over, and 0 difference.

Using the records for these same two pigs and two monkeys in Problems 3R and 3L with five, six, and seven doors in use, we have the records of Table 140 for the first twenty-four responses for each animal. When there were five doors the records (17,

18, and 20) with fifteen, sixteen, and ten rights out of the first sixteen show 96 percent of rights in responses 17 to 24, or .76 over chance, or .13 above the probability shown by the first four responses. The records (21, 22, and 24) with ten, fifteen, and nine occurrences out of sixteen which were entrances either to the wrong-end door or the next one to it, show 37½ percent which were other than those two wrongs in responses 17 to 24, or .22 less than chance, or .04 above the probability shown by the first four occurrences.

When there were six doors, the record (27) with eight rights out of the first sixteen shows 37½ percent of rights in responses 17 to 24, or .21 over chance, or .12 above the probability shown by the first four responses. The records (29, 31, and 32) with nine, eight, and six occurrences out of sixteen which were entrances either to the wrong-end door or to the one next to it, show 71 percent other than those two wrongs in responses 17 to 24, or .04 more than chance, or .21 above the probability shown in the first four responses.

When there were seven doors, the record (34) with eleven rights out of the first sixteen shows 87½ percent rights in responses 17 to 24, or .73 over chance, or .63 over the probability shown in the first four responses. The record (38) with ten occurrences out of sixteen which were entrances either to the wrong-end door or to the one next to it shows six responses out of seventeen to twenty-four, or 75 percent, which were other than those two responses, or .04 over chance, or .38 above the probability shown by the first four responses.

In these three experiments with five, six, and seven doors there is a substantial strengthening from the rewarding (an average of .58 above mere chance, and of .29 above the probability by responses 1 to 4). There is no sure strengthening of other than a wrong by the punishment of that wrong, the results in responses 17 to 24 averaging .05 below what mere chance would give and .21 above the probability by responses 1 to 4.

The strengthening of the right by the rewarding of the right response and of other than the two particular wrong responses by the punishing of them may be measured as before by the results in responses 17; 17, and 18; 17, 18, and 19; and 17, 18, 19, and 20. The fifteen, sixteen, ten, eight, and eleven rights are followed by one, two, three, and four rights, respectively, in 17,

17 + 18, 17 + 18 + 19, and 17 + 18 + 19 + 20, in four out of five, four out of five, three out of five, and two out of five cases. The excesses over chance are about .62, .77, .60, and .40. The excesses over the probabilities by responses 1 to 4 are .20, .33, .20, and .00. Comparable results for the ten, nine, fifteen, eight, six, nine, and ten occurrences of one or the other of the two wrongs are three out of seven, two out of seven, two out of seven, and one out of seven, for other than those wrongs. The differences from mere chance are about —.23, —.15, —.01, and —.06. The differences from the probabilities by responses 1 to 4 are .07, .15, .22, and .14, all excesses.

Our estimate of the relative potency of reward and punishment in the cases of these monkeys and pigs in Problem 3 will obviously depend upon the weight we attach to mere chance and to the history of the first four responses as measures of the initial strength of the connections in question, which become the strengths shown in responses 17 to 24 by reason of the training of responses 1 to 16. The use of mere chance will, on the whole, give too low an estimate of the initial strength of the right response in animals chosen because they had high percentages of rights in responses 1 to 16. In the experiments such a high percentage of rights will tend to select any animals which by some idiosyncrasy had the right tendency especially strong. For a similar reason, the use of mere chance will give too low an estimate of the strength of any one or two wrong tendencies in animals chosen because they had high percentages of these wrong responses, and so, of course, too high an estimate of the strength of connections leading to responses other than these particular wrongs.

The use of the probabilities given by the first four responses, on the other hand, though doubtless giving estimates very much nearer the true initial strengths of the connections in question, will, on the whole, give too high an estimate for the initial strength of the rights. The rights are in general increasing their strength, and will be stronger at an average position of 2½ than at the very start. Where the learning is rapid this may make a fairly large error.*

* In the cases where there are more than four choices and where the animal's frequent error or errors are due largely to some routine sequence of error at the beginning of each trial like the 6543 of 37, the probability of the particular wrong in question shown by responses 1 to 4 will be unduly high

Using the first four responses in each animal to get the strength in him and using averages weighted in proportion to the number of animals involved, we have 10½ rights plus 5½ wrongs out of 16 followed by a strengthening of .31, and 8½ of some wrong or wrongs plus 2 rights and 5½ other wrongs followed by a strengthening of other than that wrong (or those wrongs) of .09. Probably .40 and .09 will be nearer the real truth as to the strengthening than .31 and .09.

We must bear in mind also that some of the .09 is due to the potency of the occurrences of right responses along with the more frequent wrongs.

The records in Problems 2, 4, and 1 appear in Tables 141, 142, and 143.

In Table 141 we compare records 41, 43, and 46 with records 42, 44, and 45. The former averaged six rights in the first sixteen responses; the latter averaged nine 1's* in the first sixteen responses. The former had 37½ percent of rights in responses 17 to 24, or .04 above mere chance, or .21 above the probability shown in the first four responses. The latter had 58 percent other than 1 in responses 17 to 24, or .09 below mere chance, or .33 above the probability shown in the first four responses.

In the first sixteen responses with Problem 2, four choices, the animals show no differences suitable for comparison. But if we take the first forty responses we have No. 48 with eight rights out of forty and sixteen of *+1*, and No. 49 with only two rights out of forty but with twenty-three of *+1*. The former had 50 percent right in responses 41 to 48, or .25 above mere chance, or .50 above the probability shown by responses 1 to 4, or 1 to 8. The latter had 37½ percent other than *+1* in responses 41 to 48, or .37 less than mere chance, or .37 less than the probability shown by responses 1 to 4, or 1 to 8.

When these comparisons are put with those given above for Problems 3R and 3L, the final weighted average is a strengthening, by 7¾ rights of occurrences of the right response, of .20 over

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and the probability of other responses than that unduly low. The records of Problems 3R and 3L used by us (21, 22, 24, 29, 31, 32, and 38) are, however, influenced in this way very little if at all.

* The symbols 1 and + 1 of Table 141 identify two wrong responses, entering the next door to the left of the correct door and entering the next door to the right of the correct door.

the tendency shown by responses 1 to 4. Ten occurrences of some wrong or wrongs plus 2¼ rights cause a strengthening of .07½ over the tendency to give some other response than that wrong shown by responses 1 to 4. Probably .25 and .07 will be nearer the truth for the strengthenings over the real initial strengths of the connections in question.

If we assume that one rewarded right has on the average a force of .03 and one punished wrong a force of 0, we should expect .23¼ and .06¾.

In Table 142 we compare records 52 and 55 with record 53. 52 and 55 average five *c*'s and three and one-half + *1*'s in the first sixteen responses; 53 has one *c* and nine + *1*'s in the first sixteen responses. 52 and 55 averaged 31¼ percent of rights in responses 17 to 24, or .11 above mere chance, or .06 above the probability shown in the first four responses. 53 had 75 percent other than + *1* in responses 17 to 24, or .05 below mere chance, or .05 below the probability shown in the first four responses.

We also compare 58 with 56, using the records up through response 40, by which time 58 had six *c*'s and eleven *2*'s, whereas 56 had two *c*'s and seventeen *2*'s. 58 had 19 percent of rights in responses 41 to 56, or .01 below mere chance, or .07½ above the probability shown in the first eight responses. 56 had 69 percent other than *2* in responses 41 to 56, or 11 below mere chance, or .31 above the probability shown in the first eight responses.

In the case of Problem 2 with six choices we may make several sets of comparisons.

We first compare record 62 with record 60. 62 had four *c*'s and six + *1*'s in the first sixteen; 60 had no *c*'s and eight + *1*'s. In responses 17 to 24 the former had 50 percent of *c*'s, or .33 above mere chance, or 0 above the probability shown in the first four responses. The latter had 87½ percent other than + *1*, or .04 above mere chance, or 10½ percent above the probability shown by the first four responses.

We also compare these same records, 62 and 60, but using *4* as the particular wrong response. 62 had four *c*'s and two *4*'s in the first sixteen responses; 60 had no *c*'s and five *4*'s. In responses 17 to 24 the former had (as noted above) 50 percent of *c*'s, or .33 above mere chance, or 0 above the probability shown in the first four responses. The latter had 12½ percent other than *4*, or .71 below

mere chance, or .38 below the probability shown in the first four responses.

We next compare records 61 and 62 with records 59 and 60. In the first sixteen responses the former average three and one-half *c* and eight and one-half either *4* or *+1*; the latter averaged one-half *c* and ten and one-half *4* or *+1*. In responses 17 to 24 the former averaged 25 percent *c*, or .08 above mere chance, or just the same as the probability shown by the first four responses; the latter averaged .31 other than *4* or *+1*, or .36 below mere chance, or .06 below the probability shown by the first four responses.

If we measure the influence of the first twenty-four responses upon responses 25 to 32 we have an average of five and one-half *c* and twelve and one-half *4* or *+1* followed by 25 percent of *c*, or .08 above mere chance, or just the same as the probability shown by the first four responses. And we have an average of one *c* and sixteen *4* or *+1* followed by 56 percent other than *4* or *+1*, or .10 below mere chance, or .18 above the probability shown by the first four.

In the case of Problem 4 with seven choices there is no very instructive comparison possible, since the three animals had too nearly similar percentages of *c*'s. The best we can do perhaps is to compare 65 with 63 in the effect of responses 1 to 48 upon 49 to 56. 65 had ten *c*'s and thirteen *3*'s in the first forty-eight responses; 63 had three *c*'s and seventeen *3*'s. In responses 49 to 56, 65 had 25 percent of *c*'s, or .11 above mere chance, or .25 above the probability shown by the first four responses, or .12 above the probability shown by the first eight responses, or .08 above the probability shown in the first twelve responses. 63 had 87½ percent other than *3* in responses 49 to 56, or .02 above mere chance, or .37 above the probability shown by the first four responses, or .25 above the probability shown by the first eight responses, or .29 above the probability shown by the first twelve.

In the case of Problem 2 with nine choices we compare 69 with 67. For the influence of responses 1 to 16 on 17 to 24 we have four *c*'s and four of *2* or *+1* followed by 62½ percent *c*, or .51 above mere chance, or .37 above the probability shown in the first four responses, or .25 above the probability shown by the first eight responses. One *c* and eight *2*'s or *+1*'s are followed by 50 percent other than *2* or *+1*, or .27 less than mere chance, or just the same as the probability shown by the first four responses,

or .12 less than the probability shown by the first eight responses.

For the influence of responses 1 to 24 on responses 25 to 32 we have the following: Nine *c*'s and five *2*'s or +*1*'s are followed by 25 percent of *c*'s, or .14 above mere chance, 0 above the probability by 1 to 4, and .12 below the probability by 1 to 8. Three *c*'s and twelve *2*'s or +*1*'s are followed by 75 percent other than *2* or +*1*, or .02 below mere chance, or .25 above the probability by 1 to 4, or .12 above the probability by 1 to 8.

In the case of Problem 4 with nine choices we compare 71 with 70. For the influence of responses 1 to 16 on 17 to 24 we have the following: In 71, five *c*'s and six of *2*, *4* and +*4* are followed by .12 percent *c*'s, or .01 above mere chance, or .38 below the probability by the first four or the first eight. No *c*'s and twelve of *2*, *4* and +*4* are followed by 25 percent other than *2*, *4* and +*4*, or .42 below mere chance, or .75 below the probability shown by the first four, or .62 below the probability shown by the first eight.

The records for the first twenty-four responses in Problem 1 are shown in Table 143. We compare records 75 and 76, each of which shows eleven *c*'s out of the first sixteen, with records 73 and 77 which show seven and five of the wrong responses out of the first sixteen. The former show in responses 17 to 24, 75 percent of *c*'s or .41 above mere chance, or .25 above the probability indicated by the first four responses. The latter shows 75 percent of other than the wrong response 2, or .08 above mere chance, or .13 above the probability indicated by the first four responses.

As a third method we have estimated what the frequency of occurrence of the rewarded response and of each punished response will be in trials 51 to 70 by three systems, and have compared these expected frequencies with the actual frequencies to determine which fits best. We begin in each case with the strength of the respective connections as shown in trials 1 to 20.

Take, for example, Problem 2, with four doors, for monkey Sob. There are four possible entrances, C, xl, x2, and x3. We observe that in the first twenty trials these occur with frequencies of 1, 8, 3, and 8, respectively, or 5, 40, 15, and 40 per hundred. We then count the occurrences of each in Trials 21 to 50 for Sob. These were 3, 3, 3, and 21, respectively. By one system (which we will call 3, 0) we add 9 (3 for each of the 3 rewarded responses) to the initial strength of C, giving 14. We add 0 to the initial strength of

x1, for each of the three punished occurrences of it, giving 40. We add 0 to the initial strength of x2 for each of the three punished occurrences of it, giving 15. x3 similarly remains at 40. We then have 14, 40, 15, and 40, or 13, 37, 14, and 37 per hundred as the expected relative frequencies in trials 51 to 70. The actual frequencies were 5, 4, 4, and 7 or 25, 20, 20, and 35 per hundred. The difference between expectation by the 3,0 system and actuality was thus 12 + 17 + 6 + 2, or 37.*

By the second system (which we will call 3, —1) we start with the same initial status of 5, 40, 15, and 40, but multiply the occurrences in trials 21 to 50 (3, 3, 3, and 21) by 3, —1, —1, and —1, and add the products to 5, 40, 15, and 40, respectively. This gives 14, 37, 12, and 19, or 17, 45, 15, and 22 per hundred, as the expected relative frequencies in trials 51 to 70. Since the actual frequencies were, as stated above, 25, 20, 20 and 35, the difference between expectation by the 3, —1 system and actuality was 8 + 25 + 5 + 13, or 51.

By the third system (which we will call the 3,— 0.4 system) everything is done as in the second system except that the weakening by one punishment is counted as four-tenths instead of one. The difference between the expected and the actual is then 11 + 20 + 6 + 3, or 40. The 3,0 system then gives the best fit in this instance.

Computations for the 3,0 and 3,— 1 system for each set-up of the Yerkes apparatus for the crows, monkeys, and pigs in Problems 2, 3 (second at right and second at left being treated as separate set-ups), and 4, save the few in which learning was all completed before trial 70, showed that 3,0 gave much better fits than 3,— 1. So the third system, with 3,— 0.4 was tried.

The 3,0 system gives slightly closer fits than the 3,— 0.4 system, so that, so far as this treatment of these experiments with confinement as a punishment goes, they indicate a negative influence of the punishment (or a strengthening of the tendency to choose some other entrance than the punished one) that approximates zero and is less than one-eighth of the positive effect of the food reward.

The detailed results in the form of the sums of differences of expectation from actuality and the superiority of 3,0 over 3,— 1

*The difference between expectation and actuality, here and later, equals the sum of the differences regardless of signs.

TABLE 145

THE RELATIVE INFLUENCE OF REWARD BY FOOD AND PUNISHMENT BY CONFINEMENT IN EXPERIMENTS WITH THE YERKES MULTIPLE-CHOICE APPARATUS

			51–60 by 21–50					51–60 by 11–50					51–70 by 21–50					51–70 by 11–50				
			Difference of Expectation from Actuality			Amount of Superiority		Difference of Expectation from Actuality			Amount of Superiority		Difference of Expectation from Actuality			Amount of Superiority		Difference of Expectation from Actuality			Amount of Superiority	
Problem	Number of Doors	Animal	3, 0	3, −1	3, −0.4	3,0 to 3, −1	3, 0 to 3, −0.4	3,0	3, −1	3, −0.4	3, 0 to 3, −1	3, 0 to 3, −0.4	3,0	3, −1	3, −0.4	3,0 to 3, −1	3, 0 to 3, −0.4	3,0	3, −1	3, −0.4	3,0 to 3, −1	3, 0 to 3, −0.4
2	3	Sk	26	16	22	−10	− 4	44	50	46	6	2	39	26	26	−13	−13	54	60	56	6	2
		Sob	44	42	42	− 2	− 2	30	36	40	6	10	33	32	32	− 1	− 1	36	34	30	− 2	− 6
		fe	6	22	14	16	8	44	34	26	−10	−18	16	32	24	16	8	34	34	26	0	− 8
		m	74	74	72	0	− 2	100	91	100	− 9	0	74	74	72	0	− 2	102	100	100	− 2	− 2
		3	58	66	58	8	0	92	108	100	16	8	58	66	58	8	0	92	108	100	16	8
		4	96	110	102	14	6	100	116	106	16	6	98	90	82	− 8	−16	80	96	86	16	6
2	4	Sk	100	114	106	14	6	130	126	148	− 4	18	100	112	106	12	6	130	126	148	− 4	18
		Sob	27	31	24	4	− 3	42	60	36	18	− 6	37	51	40	14	3	50	80	58	30	8
		fe	36	72	58	36	22	78	106	95	28	17	46	72	58	26	12	103	106	95	3	− 8
		m	52	40	48	−12	− 4	44	48	40	4	− 4	62	50	58	−12	− 4	54	58	53	4	− 1
		3	62	78	68	16	6	50	86	58	36	8	42	58	48	16	6	26	56	38	30	12
		4	46	54	48	8	2	56	72	62	16	6	66	74	78	8	12	76	82	82	6	6
		Bab	56	80	62	24	6	94	98	106	4	12	46	68	52	22	6	57	90	102	3	15
2	5	Sk	94	90	90	− 4	− 4	102	100	100	− 2	− 2	48	52	60	4	12	73	60	66	−13	− 7
		Sob	82	84	80	2	− 2	94	96	95	2	1	66	60	62	− 6	− 4	64	66	65	2	1
		fe	61	68	64	7	3	62	64	66	2	4	51	58	54	7	3	48	44	48	− 4	0
		m	54	70	60	16	6	58	82	68	24	10	32	44	36	12	4	48	68	56	20	8
		3	72	60	82	−12	10	64	72	68	8	4	22	20	12	− 2	−10	34	30	32	− 4	− 2
		4	70	78	70	8	0	74	86	78	12	4	70	78	80	8	10	84	80	90	− 4	+ 6

2	6	m	58	66	62	8	4	46	40	48	− 6	2	40	50	50	10	10	36	44	42	8	6
		3	20	44	28	24	8	68	72	80	4	12	16	38	24	22	8	53	50	70	− 8	12
		4	72	92	78	20	6	80	86	80	6	0	74	94	78	20	4	82	86	88	4	6
		Sk	124	126	104	2	−20	143	119	138	−24	− 5	70	72	72	2	2	86	59	75	−27	− 8
		Sob	54	54	53	0	− 1	49	40	47	− 9	− 2	48	44	48	− 4	0	49	50	47	1	− 2
		fe	54	41	49	−13	− 5	68	58	64	−10	− 4	36	29	33	− 7	− 3	86	54	54	−32	−32
2	9	fe	40	73	74	33	34	81	84	82	3	1	75	66	64	− 9	−11	71	76	72	5	1
		m	34	42	39	8	5	60	52	69	− 8	9	52	64	57	12	5	80	58	80	−22	0
		Sk	87	82	90	− 5	3	75	68	76	− 7	1	87	82	90	− 5	3	107	65	74	−42	−33
		Sob	37	53	54	16	17	68	83	74	15	6	51	55	54	4	3	63	83	69	15	1
		3	54	62	52	8	− 2	58	70	46	12	−12	49	53	27	4	−22	73	80	51	7	−22
		4	90	110	98	20	8	95	140	107	45	12	44	66	48	22	4	45	98	57	53	12
3L	3	Sob	70	64	68	− 6	− 2	84	78	82	− 6	− 2	78	69	73	− 9	− 5	89	83	87	− 6	− 2
		fe	30	20	26	−10	− 4	40	28	34	−12	− 6	20	12	11	− 8	− 9	28	18	19	−10	− 9
		m	20	28	22	8	2	36	48	40	12	4	10	18	12	8	2	26	38	30	12	4
	4	Sob	58	56	58	− 2	0	48	44	46	− 4	− 2	58	58	58	0	0	48	50	46	2	− 2
		fe	28	26	26	− 2	− 2	30	30	29	0	− 1	28	26	26	− 2	− 2	30	30	29	0	− 1
		m	32	24	26	− 8	− 6	32	20	34	−12	2	46	29	36	−17	−10	42	25	44	−17	2
	5	Sob	74	74	72	0	− 2	84	90	82	6	− 2	74	74	72	0	− 2	84	90	80	6	− 4
		fe	40	56	46	16	6	59	76	68	17	9	28	36	28	8	0	49	62	54	13	5
		m	46	52	48	6	2	38	56	49	18	11	44	50	40	6	− 4	28	38	23	10	− 5
	6	Sob	138	133	135	− 5	− 3	138	126	134	−12	− 4	94	91	96	− 3	2	102	96	100	− 6	− 2
		fe	98	106	95	8	− 3	132	114	122	−18	−10	76	86	65	10	−11	102	104	92	2	−10
		m	115	114	114	− 1	− 1	110	111	113	1	3	67	64	66	− 3	− 1	67	68	69	1	2
	7	Sob	30	33	30	3	0	26	30	28	4	2	30	49	36	19	6	28	44	32	16	4
		fe	94	101	97	7	3	105	112	106	7	1	101	101	101	0	0	105	112	106	7	1
		m	92	108	104	16	12	112	112	120	0	8	92	106	98	14	6	110	101	110	− 9	0
3R	3	Sob	56	48	52	− 8	− 4	50	36	46	−14	− 4	36	28	32	− 8	− 4	32	20	26	−12	− 6
	4	fe	38	16	36	−22	− 2	33	23	30	−10	− 3	38	32	36	− 6	− 2	33	23	30	−10	− 3
		m	52	41	46	−11	− 6	58	48	54	−10	− 4	32	21	26	−11	− 6	38	38	36	0	− 2
		Sob	54	39	48	−15	− 6	46	48	48	2	2	52	31	38	−21	−14	26	20	28	− 6	2

TABLE 145 (*Continued*)

			51–60 by 21–50					51–60 by 11–50					51–70 by 21–50					51–70 by 11–50				
			Difference of Expectation from Actuality			Amount of Superiority		Difference of Expectation from Actuality			Amount of Superiority		Difference of Expectation from Actuality			Amount of Superiority		Difference of Expectation from Actuality			Amount of Superiority	
Problem	Number of Doors	Animal	3, 0	3, −1	3, −0.4	3, 0 to 3, −1	3, 0 to 3, −0.4	3, 0	3, −1	3, −0.4	3, 0 to 3, −1	3, 0 to 3, −0.4	3, 0	3, −1	3, −0.4	3, 0 to 3, −1	3, 0 to 3, −0.4	3, 0	3, −1	3, −0.4	3, 0 to 3, −1	3, 0 to 3, −0.4
	6	Sob	64	82	70	18	6	49	70	54	21	5	46	64	52	18	6	55	64	54	9	−1
		fe	34	35	34	1	0	24	21	24	−3	0	14	15	14	1	0	14	6	10	−8	−4
		m	76	84	90	8	14	76	79	58	3	−18	56	64	60	8	4	63	59	48	−4	−15
	7	fe	94	81	90	−13	−4	88	70	80	−18	−8	85	73	61	−12	−24	73	60	45	−13	−28
		Sob	106	116	89	10	−17	110	116	108	6	−2	66	76	66	10	0	74	76	70	2	−4
4	3	Sob	58	62	60	4	2	48	58	46	10	−2	56	68	60	12	4	48	60	50	12	2
		fe	18	24	20	6	2	14	28	20	14	6	8	34	10	26	2	24	38	30	14	6
		m	43	36	42	−7	−1	58	50	56	−8	−2	36	26	32	−10	−4	48	40	46	−8	−2
	5	fe	82	85	97	3	15	104	86	112	−18	8	84	90	89	6	5	106	96	100	−10	−6
		m	59	72	61	13	2	84	81	88	−3	4	59	72	72	13	13	84	81	88	−3	4
		Sob	160	142	140	−18	−20	126	174	118	48	−8	160	142	140	−18	−20	126	174	118	48	−8
	5	Sob	71	74	71	3	0	67	72	70	5	3	70	74	71	4	1	67	65	70	−2	3
	7	Sob	131	123	146	−8	15	146	128	158	−18	12	111	109	114	−2	3	126	120	128	−6	2
		fe	75	86	82	11	7	84	99	89	15	5	75	86	82	11	7	84	84	89	0	5
		m	64	70	67	6	3	88	92	95	4	7	64	70	67	6	3	88	92	94	4	6
	9	Sob	112	132	114	20	2	112	140	106	28	−4	130	121	134	−9	4	140	134	140	−6	0
		fe	101	101	102	0	1	108	106	111	−2	3	84	93	88	9	4	92	56	100	−6	8
		m	116	108	106	−8	−10	101	102	96	1	−5	76	82	80	6	4	65	59	66	−6	1

and 3,— 0.4 expectations in goodness of fit appear in Table 145. We have made computations like those described above but using the actuality in trials 51 to 60 in place of the actuality in trials 51 to 70. We have also made computations of both sorts, but using the status in trials 1 to 10 instead of that in trials 1 to 20 as the measures of initial strength and applying the systems of strengthening and weakening to the occurrences in trials 11 to 50 instead of to those in trials 21 to 50. Table 145 includes all four sets.

The median superiority of the 3,0 system over the 3,— 0.4 system is 0, 2, 2, or 0 according as we use (1) the influence of trials 21 to 50 to prophesy the change from trials 1 to 20 to trials 51 to 60, (2) the influence of trials 11 to 50 to prophesy the change from trials 1 to 10 to trials 51 to 60, (3) the influence of trials 21 to 50 to prophesy the change from trials 1 to 20 to trials 51 to 70, or (4) the influence of trials 11 to 50 to prophesy the change from trials 1 to 10 to trials 51 to 70. The probable errors of the 0, 2, 2, and 0 are, respectively, 0.4, 0.4, 0.4, and 0.5.

On the whole, then, the experiments with animals are in accord with our experiments with man. The mere punishment as such weakens a connection little or not at all. When it sets up then and there some competing response (as when it makes the animal turn and go back, or jump back, or become afraid of a certain object, or the like), it weakens the punished connection relatively. Consequently in the Warden-Aylesworth experiments it aids learning substantially; but in the experiments with confinement in the Yerkes apparatus the aid is very slight, and due perhaps to occasional attempts to retreat while the door was being closed.

*

APPENDIX IX

The use of free associations in studies of mental dynamics

Common sense warns us that a person will not knowingly incriminate or disgrace or degrade himself in a psychological experiment. In using the free association test to detect matters of morality, taste, culture, eccentricity, and the like, care and ingenuity must be exercised to hide the significance of the stimuli, or to keep track of delayed responses, or to do both. But in experiments the aim of which is knowledge of fundamental laws in mental dynamics we need not be disturbed by this. If we allow for a slight partiality toward respectable, intellectual and reasonable responses, we shall very, very rarely be misled.

Each response to a word or other stimulus in a free-association experiment is as truly the solution of a problem as it is the direct action of a stimulus. When we instruct the subject to say the first word which comes to mind or to say the first word which the stimulus word suggests, or the like, we have chiefly in mind giving the stimulus full and free chance to produce its mental effect (subject to the one condition that it be a word), but the subject may have chiefly in mind the task or problem of "Getting a word quickly" or of "Getting a word from the given word" "Getting a word that the given word suggests." He may solve this problem by sinking into a relaxed and dreamy state and blurting out the words or naming the things or facts or qualities that come to mind. He may set himself energetically to think of something after each stimulus. He may set himself to think of some word that is suggested by or fits the stimulus. To fit the stimulus may mean to him "to be a word which goes with it naturally" or "or be a word which goes with it reasonably" or both. If it means both, the relative emphasis may vary widely.

The facts concerning the occurrences and functions of words should inform us that an isolated word as a stimulus is a relatively rare event. The associative potency of a word—the total of its tendencies to evoke further mental events—whether it has come

from the repetitions and rewards of past experience or from other causes, is acquired chiefly from sentences heard, seen, spoken and written. In the case of sentences heard and seen the belonging sequences which have been most repeated and rewarded are from the word to its meaning or from expressions containing the word to their meanings. In the case of sentences spoken and written the important belonging sequences are from facts, meanings, intentions, and the like to words, not from the words to their sequents. Belonging sequences of the latter sort, though usually less important, are real. They are multifarious but certain ones deserve special notice, namely, customary expressions like six, seven (in counting), six o'clock, six or seven, six or eight, ball game, ballroom, ball and chain, ball of twine.

It is a more natural task for a person to say or write the words called up by hearing or seeing:

> One two three four five six..........
> The sun looks like a ball of..........
> He forgot to put on his collar and..........

than those called up by

> six
> ball
> collar

A final word comes more naturally to one's mind and muscles after writing

> He had a long..........

or

> We heard a loud..........

than after writing

> long

or

> loud

When we do respond to *six* or *ball* or *collar* or *long* or *loud* in the free-association experiment, the connections producing our responses are not merely certain connections ready-made and already linked with that word, but in each case an extensive mass of tendencies due to experiences of the word in contexts. Tendencies for the word to evoke its meanings, and its sequents in customary phrases are, as stated, eminent among these.

If these facts are kept in mind, the study of data from free-association experiments should be valuable, and progressively more so as more data are accumulated. Further value will be added to the data if we discover how far they are representative of the facts of thinking in general. This can be discovered by suitable experiments.

We have made a beginning by investigating the influence (1) of certain changes in the presentation of the stimulus words, and (2) of certain changes in the form of response.

We may first report the influence of changing the stimuli from those in column A to those in column B (see below). It is in the direction of reducing opposites and synonyms, and increasing sequents of the stimulus words habitual in speech and writing.

Experiment 99

We had four groups of forty, each representing a random sectioning of a group of 160 adult students. Those in the first group were given the words of column A and instructed as shown in A1 below, *i.e.*, to write one word. Those in the second were also given the words of column A, but were instructed as shown in A2 below, *i.e.*, to write two words. Those in the third group were given the words of column B and were instructed to write one word. Those in the fourth group were given the word of column B, but were instructed to write two words.

A	B	A	B
1. sweet	*in the sweet*	11. rough	*that rough*
2. whistle	*his loud whistle*	12. citizen	*any citizen*
3. woman	*a woman*	13. foot	*his foot*
4. cold	*very cold*	14. spider	*spiders*
5. slow	*is slow*	15. needle	*sharp needle*
6. wish	*his wish*	16. red	*with red*
7. river	*deep river*	17. sleep	*sweet sleep*
8. white	*whiter*	18. anger	*in anger*
9. beautiful	*how beautiful*	19. carpet	*carpet*
10. window	*our window*	20. girl	*nice girl*

A1.

Read word No. 1 and write, after it, the first word you think of. Then read word No. 2 and write, after it, the first word you think of. Then do the same with word 3, word 4, and so on.

A2.

Read word No. 1 and write, after it, the first two or three words you think of. Then read word No. 2 and write, after it, the first two or three words you think of. Then do the same with word 3, word 4, and so on.

B1.

Read the words of No. 1 and write, after them, the first word you think of. Then read the words of No. 2 and write, after them, the first word you think of. Then do the same with No. 3, No. 4, and so on.

B2.

Read the words of No. 1 and write, after them, the first two or three words you think of. Then read the words of No. 2 and write, after them, the first two or three words you think of. Do the same with No. 3, No. 4, and so on.

Writing two words instead of one does not make very much difference. There is a moderate increase in the number of sequents habitual in speech and writing at the expense of words related to the stimulus word in some other way.

The additions of this sort for the first ten words are:

sweet:	like you, potato, apples, girl graduate, as sugar
whistle:	for the dog, like a bird, blows hard
woman:	
cold:	winter day, as hell
slow:	as the deuce, down girls, moving car
wish:	for better luck, I were home, you were
river:	ran slowly
white:	as snow
beautiful:	as wifie
window:	

Writing words at the stimulation of *the sweet, loud whistle, a woman, etc.*, produces an increased effect of the same sort. The additions and some of the decreases for the first ten words are:

the sweet:	thing (three occurrences), bye and bye, girl. *Pea* and *potato* rise from three to ten occurrences; *sour* drops from eighteen to four.
loud whistle:	of the train, sounds (three). *Blow* (seven) changed to *blow* (two) and *blows* (five) and *blew*.

a woman:	friend, cried, cries, hater (two), knows, plays, reads, scolds, sings (two), smiles.
very cold:	*day*, *milk*, *morning*, *water*, *weather*, *wind*, and *winter* rise from three to nineteen occurrences.
is slow:	as, going, molasses, to, today, to move, work. *Fast* decreases from twenty-nine to five occurrences; *car*, *motion*, *moving*, and *walking* increase from two to eight.
his wish:	came (four), gets, goes, is, to do, to give, to go, was (three). *Desire* and *want* decrease from fifteen to two occurrences.
deep river:	bed, flows (three), runs.
whiter:	than (seven), than snow (two). *Black* and *blacker* decrease from twenty occurrences to two. *Snow* increases from three to nineteen. It seems likely that what was really in the mind in many of these nineteen cases was *than snow*.
how beautiful:	is (four), it, she (three), she is. *Ugly* decreases from sixteen occurrences to one.
our window:	broke, display, opens, overlooks. *Door* and *glass* decreases from fifteen occurrences to three.

When two or more words are written and the stimuli are changed as above, the change is as just shown plus a tendency to make reasonable phrases and sentences.

Experiment 100

The general fact is shown more emphatically and somewhat more exactly by Experiment 100, in which part of a large group of educated adults responded by writing two words for each of the stimulus words of column A, whereas another part of the group responded by writing two words for each of the phrases of column C. In this case we have scored each response from 1 to 5 according as it clearly was a sequence that could have been expected as a consequence of the repetition and reward of connections in speech and writing (scored 1) or clearly was not (scored 5). The sum of these twenty scores gives a definite measure of the relative prevalence of the two sorts. The average for responses to the words of column A is 76; for responses to the phrases of column C is 35.

The same individuals who responded to the words of Column A responded also to the phrases of Column C1, and those who responded to the phrases of Column C responded also to the words of Column A1. The average score in the case of the words of Column A1 was 80; that for the phrases of Column C1 was 47. For the entire series we then have an average score of 78 for responses to the single words and 41 for the responses to the phrases,

with equalization as to the subjects.* Table 146 presents all the scores.

What these scores mean concretely may be realized from the samples below which are for the individuals nearest to 76, 35, 80 and 47 in the four sets of twenty responses.

A	A1	C	C1
1. sweet	*memory*	1. in the sweet	*in his memory*
2. whistle	*sheep*	2. his loud whistle	*but for sheep*
3. woman	*bath*	3. for a woman	*and your bath*
4. cold	*swift*	4. and very cold	*his new cottage*
5. slow	*cottage*	5. he is slow	*it is swifter*
6. wish	*blue*	6. was his wish	*this light blue*
7. river	*hungry*	7. this deep river	*we were hungry*
8. white	*priest*	8. whiter	*the priest*
9. beautiful	*ocean*	9. how beautiful	*Atlantic Ocean*
10. window	*head*	10. our window	*our window*
11. rough	*stove*	11. in that rough	*that hot stove*
12. citizen	*long*	12. so any citizen	*for long*
13. foot	*religion*	13. did his foot	*if Christian religion*
14. spider	*child*	14. of spiders	*such a child*
15. needle	*whiskey*	15. this sharp needle	*and bad whiskey*
16. red	*bitter*	16. with red	*that letter*
17. sleep	*hammer*	17. sweet sleep	*that hammer*
18. anger	*thirsty*	18. in anger	*so thirsty*
19. carpet	*city*	19. carpet	*their city*
20. girl	*square*	20. nice girl	*in square*

* There was also approximate equalization in respect of whether responses to words or to phrases was made first, fifty-nine individuals doing the former and fifty-five the latter. As would be expected responding to single words first makes the responses to both have somewhat higher scores, that is fewer habitual sequences, but the differences are slight (83 1/3 to 74 and 42½ to 39½).

TABLE 146

SUM OF SCORES FOR EACH INDIVIDUAL WHEN THE RESPONSES CLEARLY DUE TO HABITUAL SEQUENCES ARE EACH SCORED 1, AND THOSE CLEARLY NOT DUE TO HABITUAL SEQUENCES ARE EACH SCORED 5, DOUBTFUL RESPONSES BEING SCORED 2, 3, OR 4

Group I Singles First		Group II Singles First		Group III Phrases First		Group IV Phrases First	
Singles: sweet, etc.	Phrases: in his memory, etc.	Singles: memory, etc.	Phrases: in the sweet, etc.	Singles: sweet, etc.	Phrases: in his memory, etc.	Singles: memory, etc.	Phrases: in the sweet, etc.
100	20	81	24	79	32	96	28
60	52	100	37	100	100	100	100
100	28	100	44	64	52	42	24
96	32	60	26	20	20	64	41
25	22	100	100	100	96	96	24
24	20	100	32	100	30	33	29
60	30	100	21	76	36	96	36
100	20	96	35	39	34	61	48
66	32	96	59	96	24	54	28
100	44	100	92	24	20	84	21
93	56	100	20	88	35	88	33
100	68	100	28	89	26	100	48
100	40	100	24	84	27	96	20
96	27	100	41	64	32	69	36
98	100	96	45	32	29	92	32
88	64	64	20	100	89	96	40
20	25	100	21	100	100	72	40
100	88	96	28	96	57	60	24
88	20	25	20	100	84	85	28
40	30	88	24	96	37	40	24
100	96	100	100	60	24	24	24
100	72	100	38	100	44	100	35
100	100	85	36	35	28	49	20
89	23	68	21	34	20	80	32
20	20	96	52	87	48	96	24
92	24	100	24	20	21	100	24
20	24			80	28	33	23
96	68			63	56	97	28
100	72			97	56	24	20
64	32			98	100	72	36
100	100			100	100	40	27
96	44					57	22
20	20					84	28
						96	32

A Record Scoring 76

1. sweet	spring flower	11. rough	weather sea
2. whistle	brother home	12. citizen	of U. S.
3. woman	man child	13. foot	hose slaves
4. cold	day night	14. spider	web summer
5. slow	train delay	15. needle	thread thimble
6. wish	for gold	16. red	dress ribbon
7. river	ran swiftly	17. sleep	long late
8. white	dress sleeves	18. anger	temper woman
9. beautiful	girls women	19. carpet	sweeper vacuum
10. window	shade curtains	20. girl	boy woman

A Record Scoring 35

1. in the sweet	summer time	11. in that rough	sea breeze
2. his loud whistle	rang clearly	12. so any citizen	can do
3. for a woman	and man	13. did his foot	hurt him
4. and very cold	weather too	14. of spiders	web fly
5. he is slow	and stupid	15. this sharp needle	is bright
6. was his wish	to be	16. with red	roses and
7. this deep river	was cold	17. sweet sleep	small child
8. whiter	than snow	18. in anger	and fear
9. how beautiful	it is	19. carpet	sweeper rug
10. our window	was open	20. nice girl	and boy

A Record Scoring 80

1. memory	trained to	11. stove	porcelain pretty
2. sheep	woolly Montana	12. long	wish for
3. bath	salts Saturday	13. religion	creed believe
4. swift	and hurried	14. child	play run
5. cottage	lake sunset	15. whiskey	bad hot
6. blue	and gray	16. bitter	sweet pretty
7. hungry	but glad	17. hammer	and tongs
8. priest	church holy	18. thirsty	cool water
9. ocean	wide cross	19. city	life noise
10. head	cold sick	20. square	round blue

A Record Scoring 48

1. in his memory	in Memoriam	11. that hot stove	is black
2. but for sheep	dog sheep	12. for long	too short
3. and your bath	towel and soap	13. if Christian religion	were known
4. his new cottage	a bungalow	14. and bad whiskey	were abolished
5. it is swifter	than Lindbergh	15. such a child	would develop
6. this light blue	color design	16. that letter	correctly spelled
7. we were hungry	all day	17. that hammer	is heavy
8. the priest	is gowned	18. so thirsty	am I
9. Atlantic Ocean	Pacific Ocean	19. their city	is small
10. our window	is broken	20. in square	on circle

The facts are then as follows: A word alone calls up its frequent and fit sequent in speaking and writing if there is such a one strongly connected with it. If there is not, it follows the lead of the word-meaning connections and calls up some word which they produce. When the word is prefaced by *the, a, his, our, that, sharp, very, in,* and the like, the speaking-writing connections become somewhat stronger, and when the word is still more emphatically part of a statement or question (as *in the sweet, his loud whistle, for a woman, and very cold, etc.*), the speech-writing connections become relatively very strong.

For most studies of mental dynamics, the word-meaning connections are not likely to be so instructive as connections revealing what a person would say or write. The latter are more representative of what he would know or think or do or feel. Consequently writing words in response to a stimulus which could be a fragment of many different thoughts has certain advantages over writing words in response to single words. Writing words under some still more definite direction of response has in certain respects still greater advantages. Hence such forms as these may be useful:

Write the name of something that is:

dark ....
deep ....
soft ....
black ....

Write words to complete these:

The music was ....
Sickness is ....
Eating is ....
The river was ....
A mountain has ....
A house has ....
A butterfly has ....
A girl has ....
A man can ....
A citizen can ....
A girl can ....
A soldier can ....

For studies of individual eccentricity, peculiarities, interests, aversions, "complexes," and the like, the free-association experiment, with response by a word to a word, is a useful instrument. But the reasons for its usefulness are not those which have been

commonly assumed. The common assumption has been that the stimulus word makes a person think of the thing or quality or fact that it names, and that this thing or quality or fact calls up something else, the word for which the subject then writes. This is apparently very rarely the case, occurring in perhaps 5 percent of Kent-Rosanoff responses. About 95 percent of the responses are due to connections formed with the stimulus words in hearing and reading, and in speaking and writing. They reveal chiefly what the individual has heard, read, said and written, weighted by his interest therein, and what connections have operated to give meaning to words heard and seen.

The community of responses is in large measure due to the word-meaning and word-use connections. A person who oversteps this often may well be eccentric and unbalanced and with a sick brain. But this is not so much because he shows perversity in the concrete ideas which come when he hears the words, as because he shows derangement of the basal layer of connections by which words acquire meanings or direct speech.

Similarly the importance of the signs of "complexes" associated with certain words does not lie so much in the fact that the "complex" outweighs a normal interest in certain objects and facts, as in the fact that it outweighs a basal organization of habits, comparable to walking to the place where one wishes to be, swallowing what has been chewed, or holding a book right side up.

For the general study of interests and attitudes the free-association test with a word for a word is useful, not so much because each response is in large measure the product of an individual interest, as because most of them are not. The material furnished is scanty, but it is presumably relatively free from efforts to make a good showing and from erroneous self-evaluations which the person has adopted. Its great merit as a test of interests is that the majority of the connections operate rather fluently as a consequence of the meaning-bonds and use-bonds so that the subject may be less on his guard in the few cases where his interests do determine responses.

APPENDIX X

Experiments with associative shifting and conditional reflexes

This appendix reports the results of an attempt to secure from human subjects conditional reflexes analogous to those obtained in animals.

The Watson apparatus for securing the palmar reflex was redesigned to obtain records by electromagnetically activated needles,

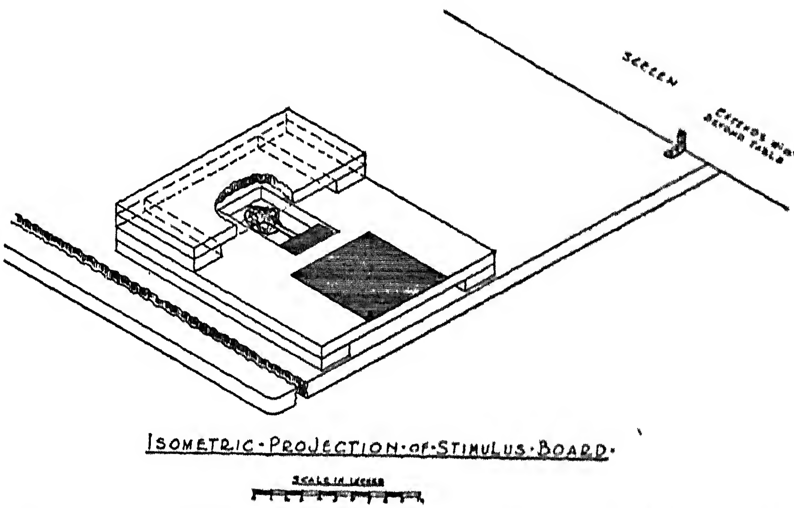

Figure 17. The stimulus board used in experiments with conditional reflexes.

thereby eliminating the appreciable lag of pneumograph recording. The apparatus consisted essentially of two electrical contacts—a brass plate and a remodeled telegraph key mounted on the stimulus board (See Figure 17). The stimulus board consisted of a base board ¾ x 12 x 14 inches on which was mounted at front center a brass plate 5½ x 5½ inches. In a slot 3 x 5½ inches a telegraph key was sunk so that a brass lever 1 x 2¾ inches which replaced the knob of the arm was one inch beyond the large brass plate. This

brass lever was insulated from the key arm, and so placed that when the palm and fingers were placed flatly in position the pressure of the three middle fingers would bring the lever flush with the brass plate.

The wiring was so arranged as to enable the experimenter to give a vibratory shock to the subject's palm by means of a DuBois

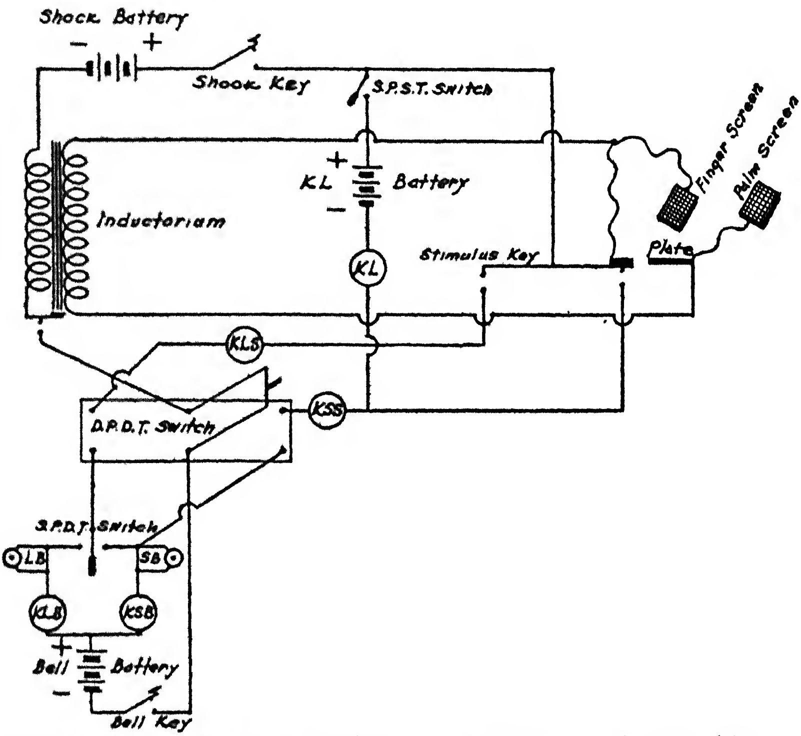

FIGURE 18. The electrical circuit employed in the experiments with conditional reflexes.

Reymond inductorium either when the lever was depressed, or when the lever was released, and to ring one of the two bells. The complete circuit is shown in the diagram—Figure 18. The bell circuit was independent of the shock circuit. When the DPDT switch was thrown to the right, the bell key operated the stimulus bell (SB), and the depression of the shock key shocked the subject only as long as he held the lever down. As soon as the lever was released, the primary circuit was broken. When the DPDT switch was thrown to the left, either the stimulus bell or the lift bell might

be put into operation upon closing the proper circuit with the SPDT switch. In the left position of the DPDT switch, the shock could be given only when the lever was not depressed. This shock was given through two screens, one of which was taped about the upper joints of the three middle fingers, the other of which was taped about the lower palm. When the DPDT switch was thrown left, the shock circuit could be broken only by the subject on depressing the lever. The lever which was mounted on the telegraph key was arranged to secure a contact at the rear of the instrument, which was insulated from the base and the front contact.

In series with each bell was an electromagnetically activated needle KSB and KLB which recorded whenever the bell was being rung; in series with each shock circuit there were electromagnetically activated needles, KSS and KLS which recorded whenever the subject was receiving a shock. A fifth needle operated by a separate set of cells wired so that the polarity was opposed to that of the shock battery (to prevent activation of the lift needle) recorded each time the lever was released. Each circuit operated on three dry cells, which were renewed so as to keep voltmeter and amperage readings the same in the three circuits. Readings were taken on smoked-paper by kymograph. All apparatus save the stimulus board was screened from the subject by means of a beaver-board partition which extended two feet beyond the table, separating the subject from the experimenter.

Experiment 101

This experiment was designed to discover in whom the so-called conditional response to the bell was developed and how quickly such a response was formed.

The subject was seated in a chair having a right arm for writing. On the right arm was placed the book which the subject had brought to read, or some interesting book provided by the experimenter. About his left hand were taped the two screens of fine brass wire mesh,* one about the upper joints of the three middle fingers, the other about the lower palm.

The subject was then told, "Place your hand on the stimulus board so that your palm rests on the large plate and the three middle fingers touch the lever. Press the lever. You see but a slight pressure is required to depress the lever. The position of the hand during the experiment is with the key depressed. You are to read,

* These were not used in Experiment 101, but were placed so as to be in position if the subject should be used also for Experiment 103.

forget about your hand, allowing it to react normally. Go ahead and read. I will tell you when I am ready."*

The switches were set for the stimulus bell to be rung and for the shock to be given while the lever was depressed. The kymograph was placed in position, and the needles aligned. Then the subject was told, "Ready, depress."

The bell alone was rung for four seconds each time for five times to guarantee that the subject did not have the lift reaction to the bell. Then the shock alone was given until the minimal shock to which the subject would lift or raise his fingers ten times out of ten stimulations was ascertained. *Bell and shock* and *bell alone* were then administered in various orders so that the average ratio of *bell and shock* to *bell alone* was four to one. In giving *bell and shock*, the bell was rung for two seconds and then the shock given while the bell continued ringing for two more seconds. It should be noted that when the *bell and shock* were administered, the subject could not get the shock if he lifted his hand any time during the two seconds during which the bell was ringing, even when the experimenter closed the shock circuit, since the lift of the hand broke the circuit on the subject's side.

There were then four possible events, as follows:

If the subject was stimulated by *bell and shock* and his fingers rose, the response was recorded as BSR (to be read as bell and shock, rise).

If the subject was stimulated by *bell and shock* and his fingers did not rise, the response was recorded as BSNR (to be read as bell and shock, no rise).

If the subject was stimulated by *bell alone* and his fingers rose, the response was recorded as BR (to be read as bell, rise).

If the subject was stimulated by *bell alone* and his fingers did not rise, the response was recorded as BNR (to be read as bell, no rise).

The set-up favored the securing of the BR response, not only because of the overlapping of the unconditional stimulus, but also by preventing shock if the BR response was developed.

This program of *bell alone* and *bell and shock* was continued until one of four events occurred:

(1) Expiration of time. (Two hours was the limit of a session.)
(2) Complaint of pain.
(3) The securing of a response of not reacting to the combined *bell and shock* nineteen out of twenty times.

* These directions were explained when necessary to be sure that the subject understood what was to be done.

(4) The securing of the so-called conditional response of lift to *bell alone* nine times out of ten stimulations.

At the end of the experiment, each subject answered the following questions:

1. Did you ever intentionally take your fingers off the lever or otherwise let it come up?............
2. If so, when and how often?....................................
3. Did you ever intentionally hold the lever down while the bell was ringing?............
4. If so, when and how often?...................................

The records of those who answered *No* to questions 1 and 3 (or of those whose *Yes* was so qualified as to be practically a *No*) concern us. In Table 147 are recorded the last fifty responses as recorded, and a summary of those responses for the subjects who answered *No* to questions 1 and 3.

TABLE 147

THE ANALYSIS OF THE LAST FIFTY RESPONSES OF THE SUBJECTS WHO ANSWERED THE QUESTIONS AFTER EXPERIMENT 101 THUS: (1) NO; (2) —; (3) NO; (4) —

BSR represents the combined stimulus *bell and shock* with the response of lift or rise.
BR represents the stimulus of *bell alone* with the response of lift or rise.
BSNR represents the combined stimulus of *bell and shock* with the response of *no* lift or rise.
BNR represents the stimulus of *bell alone* with the response of *no* lift or rise.

	Summary of the Last Fifty Responses by Type					Reason for	
Subject	BSR	BR	BSNR	BNR	The Last Fifty Responses	End of Experiment	B+BS Total
M De	39	5	0	6	BSR 9, BNR 1, BSR 2, BNR 2, BSR 4, BNR 1, BSR 5, BNR 1, BSR 3, BR 1, BSR 4, BR 1, BSR 4, BR 2, BSR 3, BNR 1, BSR 4, BR 1, BSR 1	Discarded—complaint of pain.	424
J McK	19	21	0	10	BSR 6, BR 2, BNR 1, BSR 3 BR 3, BSR 2, BR 6, BSR 3, BR 3, BNR 1, BR 4, BNR 2, BSR 2, BR 1, BSR 1, BR 2, BNR 3, BSR 1, BNR 1, BSR 1, BNR 2	time up	859
B Go	36	0	5	9	BSR 3, BNR 1, BSR 1, BNR 1, BSR 1, BSNR 2, BSR 1, BNR 1, BSR 4, BNR 1, BSR 4, BNR 2, BSR 9, BSNR 1, BSR 2, BSNR 2, BSR 3, BNR 1, BSR 8, BNR 2	time up	709
W Ca	17	13	9	11	BSR 1, BNR 1, BSNR 1, BSR 2, BNR 1, BSR 1, BR 1, BSR 1,	time up	803

TABLE 147 (*Continued*)

Subject	Summary of the Last Fifty Responses by Type				The Last Fifty Responses	Reason for End of Experiment	B+BS Total
	BSR	BR	BSNR	BNR			
					BR 1, BNR 2, BSR 2, BSNR 2, BSR 2, BSNR 1, BSR 1, BNR 1, BR 1, BSNR 4, BR 2, BSR 2, BNR 1, BR 1, BSR 3, BR 3, BNR 1, BSNR 1, BSR 1, BR 1, BNR 2, BSR 1, BR 3, BNR 2		
M Re	19	13	10	8	BSR 1, BSNR 1, BNR 1, BR 2, BSR 3, BR 1, BNR 2, BSR 1, BR 1, BSR 1, BR 1, BSR 1, BR 1, BSNR 3, BSR 1, BNR 1, BR 1, BNR 1, BSR 1, BSNR 1, BSR 3, BR 2, BSR 1, BR 1, BNR 1, BR 1, BNR 1, BSR 1, BNR 1, BSNR 2, BSR 1, BR 1, BSR 1, BR 1, BSR 1, BSNR 1, BSR 1, BSNR 2, BSR 1	time up	651
L Fa	23	1	18	8	BSNR 8, BSR 4, BNR 2, BSR 8, BR 1, BNR 1, BSR 2, BNR 2, BSR 5, BNR 3, BSR 2, BSNR 10, BSR 2	time up	700
R Bo	5	22	0	23	BR 2, BSR 2, BNR 1, BSR 3, BR 1, BNR 1, BR 1, BNR 3, BR 4, BNR 1, BR 1, BNR 1, BR 1, BNR 5, BR 6, BNR 7, BR 3, BNR 1, BR 2, BNR 3, BR 1	time up	1275
F Cr	4	3	40	3	BSNR 13, BSR 2, BSNR 2, BSR 1, BSNR 1, BNR 1, BR 3, BSNR 15, BSR 1, BSNR 4, BNR 2, BSNR 5	19x20 BSNR	424
C Mo	9	0	34	7	BSR 3, BSNR 1, BNR 2, BSR 3, BNR 1, BSR 1, BSNR 1, BSR 1, BSNR 1, BNR 1, BSNR 1, BNR 1, BSNR 7, BSR 1, BNR 2, BSNR 23	20x20 BSNR	194
R Ke	3	0	45	2	BSNR 5, BSR 1, BSNR 1, BNR 2, BSNR 2, BSR 1,BSNR 6, BSR 1, BSNR 31	20x20 BSNR	502
S At	4	0	46	0	BSR 1, BSNR 15, BSR 2, BSNR 29, BSR 1, BSNR 2	20x20 BSNR	647
I Jo	0	1	49	0	BSNR 7, BR 1, BSNR 42	20x20 BSNR	70
H Wo	4	0	45	1	BSR 2, BNR 1, BSR 1, BSNR 25, BSR 1, BSNR 20	20x20 BSNR	586
A Ga	4	0	44	2	BSR 1, BSNR 1, BSR 1, BNR 2, BSR 1, BSNR 10, BSR 1, BSNR 33	20x20 BSNR	149
M Ja	4	0	45	1	BSNR 11, BSR 1, BSNR 11, BSR 1, BSNR 2, BSR 1, BSNR 19, BSR 1, BSNR 1, BNR 1, BSNR 1	20x20 BSNR	724
A Ba	3	0	45	2	BSNR 3, BNR 2, BSNR 9, BSR 3, BSNR 33	20x20 BSNR	95
W Sa	0	0	50	0	BSNR 50	20x20 BSNR	454
P Ca	2	1	47	0	BSR 1, BR 1, BSNR 1, BSR 1, BSNR 46	20x20 BSNR	310
J Ri *	14	1	24	1	BSR 8, BR 1, BNR 1, BSR 6, BSNR 24	20x20 BSNR	40

* Only forty responses to status 20x20 BSNR.

An inspection of Table 147 will indicate that of the group answering *No*; —; *No*; —; one subject, M De, was discontinued because of complaint of pain, six subjects participated in the experiment for the two hours of the experiment, and twelve ceased the experiment upon reaching a condition of not lifting the hand for at least nineteen out of twenty stimulations with combined *bell and shock.*

Two of them showed no tendency for the hand to rise at the *bell alone* (BR 0, BNR 9, for B Go and BR 1, BNR 8, for L Fa during the last fifty stimulations by BS or B). In the other four, the records for B stimulations among the last fifty were as follows:

R Bo	BR 22	BNR 23
A Ca	" 13	" 11
M Re	" 13	" 8
J McK	" 21	" 10

These are the nearest approaches to the typical conditional reflex that we found in the *No*; —; *No*; —; group.

It may be that the subject J McK would with time have developed a stable BR connection, although the details of the last fifty responses (see Table 147) do not support this conclusion.

An equally important fact is the change from BSR to BSNR which was shown by twelve subjects of this group. The shock initially caused a lift ten times out of ten, yet, after combined stimulus of *bell and shock* from 32 to 450 times, the subject failed to respond. The explanation of this reaction may lie in alterations in the subject's bodily resistance, sensitivity, tolerance, or interest in the shock in comparison with other elements of the situation.

Whatever the explanation, it is apparent that the so-called conditional response is not secured from all human subjects, and that a response quite different from the conditional response is obtained more frequently.

The answers of all subjects (save those reported in Table 147) to the four questions of Experiment 101 are given in Table 148 together with the experimenter's decision regarding the use of the record. Wherever from the subject's answer it was possible to assume or infer practical non-intent in reacting to the stimuli the records were used. These records are given in Tables 149, 150, and 151.

The analysis of the records of those who answered *Yes* to either questions 1 or 3 or both, but whose responses were qualified so

TABLE 148

THE RESPONSES OF THE SUBJECTS WHO ANSWERED THE FOUR QUESTIONS AFTER EXPERIMENT 101 WITH ANSWERS OTHER THAN: (1) NO; (2) —; (3) NO; (4) —; WITH RESULTING ACTION REGARDING RECORD

Subject	Responses	Action
H Br	1. No 2. — 3. Yes 4. During first hour four times	Reported in Table 149
M Ja	1. No 2. — 3. Yes 4. Two or three times at beginning	Reported in Table 149
A Go	1. No 2. — 3. Yes 4. Five at utmost. Toward end of first five parts	Reported in Table 149
M He	1. Yes. Two or three times near beginning 2. — 3. Yes 4. Middle—four or five times	Reported in Table 151
L Ic	1. Yes 2. In the beginning about six times 3. Yes 4. At first about four or five times	Reported in Table 151
J Tu	1. No 2. — 3. Yes 4. At the beginning of the experiment. About twenty times	Reported in Table 149
L Ho	1. No 2. — 3. Yes 4. Occasionally—after the investigator had just asked me to "press down on the lever"	Reported in Table 149
C Me	1. Yes 2. I think about twice 3. No 4. —	Reported in Table 150
M Wh	1. Yes. Six times to replace hand more in the middle 2. — 3. No 4. —	Reported in Table 150
E Mo	1. Yes 2. Once 3. No 4. —	Reported in Table 150
D Ji	1. Once or twice 2. Not more than once or twice and that only towards the end 3. Maybe again once or twice 4. In the middle of the experiment	Reported in Table 151
M Bu	1. Yes 2. When I was told to rest; once or twice when I noticed the experimenter left the chair 3. No 4. —	Reported in Table 150

TABLE 148 (*Continued*)

Subject	Responses	Action
J Bj	1. Only two or three times to adjust tape over the fingers 2. — 3. Yes, at first for fifteen or twenty minutes when my reading material was not holding my attention as definitely. I was more conscious of making an effort to hold the lever down 4. —	Discarded
H Wa	1. Yes 2. I think each removal of the hand was conscious and volitional. I decided that I would relieve myself to that extent 3 I decided once for all to keep the key down 4. Answered in 3	Discarded
R Du	1. Yes 2. Almost always whenever my hand came up for any considerable time 3. Yes, sometimes 4. When I felt that I had previously let my hand up too much. About twenty times during the experiment	Discarded
H Mo	1. Yes 2. When an electric current was being given and the bell was still ringing Rather frequently 3. Yes 4. In the beginning when the current seemed stronger	Discarded
M Bo	1 Yes 2. Twice that I knew of 3 Yes 4 Directly after a shock with the bell. As often as the shock was real severe. About four times that I know of. Shock varied in severity and type. Occasionally hand was affected, occasionally each finger except my thumb and several times hand and wrist. Four [sic] finger (next pinkie) had peculiar pain at knuckle joint. Pain went completely around finger and seemed to be jerking it outward	Discarded. Abandoned experiment because of acute pain
G Wa	1. Yes 2. When I felt the shock. Not always paying attention, but probably a third of the time 3–4. Yes, when I felt clear that no shock was coming	Discarded
A Mo	1. Yes 2 All time 3. Yes 4. Tried to see how much I could stand toward end didn't care	Discarded
L Co	1. No 2. — 3 Yes 4. Each time bell rang	Discarded
E Cl	1. I did not think of raising my finger when I started reading. I thought I will continuously press the key 2. Not at all 3. Not more so than at another time 4. Not at all	Discarded
G Fo	1. Yes 2. One out of twenty-five cases or less 3 Yes 4. One out of fifteen cases I find that if the shock is administered at the beginning of the ringing of the bell for two or three times in succession then three or four times as the case may be I found that I almost invariably broke the connection even though I felt no shock	Discarded

TABLE 148 (*Concluded*)

Subject	Responses	Action
P Su	1. Yes 2. About twenty times due to discomfort throughout 3 Yes 4. About twenty times due to curiosity	Discarded. Abandoned experiment because of complaint of acute pain in arm
E Ac	1. Yes 2. When the pain became too intense. Approximately 100 times 3. Yes 4. When I became absorbed in my reading and when I deliberately forced myself to do so	Discarded
S Wa	1. Yes 2. In the beginning the shock seemed more severe and I released the contact temporarily to react from the shock once when the operator said "Depress" I thought he said "Rest" and removed my hand 3 Yes 4. If my mind was not absorbed in what I was reading, I pressed the lever about every fourth time the bell rang. During the latter part of the experiment I did not always hear the bell	Discarded
M Br	1. Yes 2. After I discovered the shock comes after the bell rang I took my hand off as soon as the bell rang 3. Yes 4. Near the end of the experiment I tried keeping the lever down and finding the shock no longer came I kept my hand down all the time	Discarded
E Ko	1. No 2. — 3 Yes 4. Always held my fingers down until I felt current	Discarded
A Ko	1. Yes 2. — 3. No 4. —	Discarded

as to be practically *No* will be considered. Tables 149, 150, and 151 show the facts.

Of the twelve subjects of Tables 149, 150, and 151, six showed the response BSNR at least nineteen out of twenty times, four showed BR at least nine times out of ten with reinforcement, and two, who worked for the entire period, showed in the last fifty BSR, BR, BSNR, BNR, 31 and 28, 0 and 8, 9 and 1, and 10 and 12, respectively.

This group of individuals who may have encouraged the hand to rise at the *bell alone* show a closer approach to a firm connection of B with R than the *No*; —; *No*; —; group. Whereas before we had fourteen clear absences of this phenomenon and four partial appearances of it, we now have seven clear absences, one partial appearance, and four clear appearances.

In all, fifty-three subjects, graduate students and members of

TABLE 149

THE ANALYSIS OF THE LAST FIFTY RESPONSES OF THE SUBJECTS WHO ANSWERED THE FOUR QUESTIONS AFTER EXPERIMENT 101 THUS: (1) NO; (2) —; (3) YES; (4) QUALIFICATION OF (3) TO PRACTICAL NO

	Summary of the Last Fifty Responses by Type					Reason for End of	B+BS
Subject	BSR	BR	BSNR	BNR	The Last Fifty Responses	Experiment	Total
A Go	9	39	0	2	BSR 3, BR 5, BSR 1, BR 10, BSR 1, BR 3, BSR 1, BR 3, BNR 2, BSR 2, BR 6, BSR 1, BR 12	BR 10x10 reinforced	226
M Ja	7	0	38	5	BSR 2, BNR 1, BSR 1, BSNR 3, BNR 1, BSR 2, BSNR 2, BNR 1, BSNR 9, BSR 1, BNR 2, BSNR 23, BSR 1, BSNR 1	BSNR 20x20	89
H Br	12	2	33	3	BSNR 4, BSR 1, BNR 1, BSR 1, BSNR 1, BNR 1, BSNR 9, BSR 1, BSNR 16, BSR 1, BSNR 1, BSR 3, BNR 1, BSR 1, BR 1, BSR 1, BR 1, BSNR 2, BSR 3	BSNR 19x20	476
L Ho	1	0	48	1	BSNR 11, BSR 1, BSNR 3, BNR 1, BSNR 34	BSNR 20x20	144
J Tu	8	0	37	5	BSR 1, BSNR 1, BSR 2 BNR 2, BSNR 5, BSR 1, BSNR 1, BSR 2, BNR 1, BSR 1, BSNR 23, BSR 1, BSNR 5, BNR 2, BSNR 2	BSNR 20x20	1736

TABLE 150

THE ANALYSIS OF THE LAST FIFTY RESPONSES OF THE SUBJECTS WHO ANSWERED THE FOUR QUESTIONS AFTER EXPERIMENT 101 THUS: (1) YES; (2) QUALIFICATION OF (1) TO PRACTICAL NO; (3) NO; (4) —

	Summary of the Last Fifty Responses by Type					Reason for End of	B+BS
Subject	BSR	BR	BSNR	BNR	The Last Fifty Responses	Experiment	Total
E Mo	3	0	43	4	BSNR 4, BSR 1, BNR 3, BSNR 1, BSR 1, BNR 1, BSR 1, BSNR 38	BSNR 20x20	310
M Wh	31	0	9	10	BSR 2, BNR 2, BSR 3, BSNR 1, BSR 1, BNR 1, BSR 7, BNR 1, BSR 1, BSNR 4, BSR 1, BNR 1, BSR 3, BNR 1, BSR 2, BSNR 2, BSR 1, BNR 1, BSR 1, BSNR 1, BSR 2, BNR 1, BSR 4, BNR 1, BSNR 1, BSR 3, BNR 1	time up	800
C Me	29	8	1	12	BR 4, BSR 5, BNR 1, BSR 1, BSNR 1, BSR 3, BR 1, BSR 2, BNR 1, BR 1, BSR 1, BR 1, BSR 8, BR 1, BNR 2, BSR 5, BNR 3, BSR 4, BNR 5	time up	522
M Bu	10	40	0	0	BSR 3, BR 2, BSR 1, BR 6, BSR 1, BR 11, BSR 1, BR 2, BSR 1, BR 6, BSR 2, BR 6, BSR 1, BR 7	BR 10x10 reinforced	529

TABLE 151

THE ANALYSIS OF THE LAST FIFTY RESPONSES OF THE SUBJECTS WHO ANSWERED THE FOUR QUESTIONS AFTER EXPERIMENT 101 THUS: (1) YES; (3) YES; (2) AND (4) QUALIFICATIONS OF (1) AND (3) TO PRACTICAL NO

Subject	Summary of the Last Fifty Responses by Type BSR	BR	BSNR	BNR	The Last Fifty Responses	Reason for End of Experiment	B+BS Total
D Ji	9	39	0	2	BR 4, BSR 1, BNR 1, BR 3, BSR 1, BR 6, BSR 1, BR 5, BSR 1, BR 1, BSR 1, BR 2, BSR 1, BR 6, BSR 2, BR 4, BNR 1, BSR 1, BR 8	BR 10x10 reinforced	674
M He	13	1	34	2	BSR 10, BR 1, BSR 2, BSNR 2, BNR 2, BSNR 12, BSR 1, BSNR 20	BSNR 20x20	131
L Ic	10	29	0	11	BSR 1, BR 4, BSR 1, BR 3, BSR 2, BR 10, BSR 1, BR 3, BNR 9, BSR 1, BR 2, BSR 2, BR 1, BNR 2, BSR 1, BR 6, BSR 1	BR 10x10 reinforced	191

the faculty, in residence at Teachers College, or at Columbia University, participated in this experiment. Nineteen are accounted for in Table 147 and twenty-eight in Table 148; six subjects are not reported in either table. Of these six, two subjects were discontinued for each of these three reasons:

(1) Fear of apparatus.
(2) The response to the bell alone before training.
(3) The failure to respond to 0 cm. of shock before training.*

Of fifty-three subjects

6 did not taking the training.
16 allowed volition to influence the response (reported in Table 148 as discarded).
8 worked to the expiration of time, three with clear non-appearances and five with partial appearances of the BR connection.
1 was abandoned because of complaint of pain (complaint-pain).
18 reached a condition of responding to the combined *bell and shock* by *no rise* in nineteen out of twenty trials.
4 showed a response which may be the conditional reflex, *bell alone* being followed by *rise* in 9 out of 10 trials.

Under the conditions of this experiment a conditional reflex is formed rarely if at all. The response BR was obtained in about

* H Mo and M O'B discontinued for fear of apparatus; M Ka and H Kr discontinued for BR before training; B Mo and M Gi discontinued for non-response to 0 cm. of shock (maximum strength).

8 percent of the subjects, while BSNR was obtained in 34 percent of the subjects.

Experiment 102

Subjects A Go, M Bu, D Ji, L Ic, who showed BR, nine times out of ten, in the last fifty trials of Experiment 101 were used as subjects in Experiment 102.

To secure experimental extinction after the conditional response had been secured to a strength of nine out of ten, and reinforced by 20 B and 5 BS, bell stimulations were given until failure of the R nine times out of ten or seventeen times out of twenty, or until 100 B alone had been given.

A Go was given 108 *bell alone* to which he responded, 106 BR and 2 BNR.

M Bu was given 109 *bell alone* to which she responded, 105 BR and 4 BNR.

L Ic was given 110 *bell alone* to which he responded, 106 BR and 4 BNR.

D Ji was given 91 *bell alone* to which he responded, 57 BR and 34 BNR, successive tens of which were responded to by 9, 9, 8, 9, 7, 6, 7, 2 and 0 BR.

In but one of these four subjects of Experiment 102 was experimental extinction obtained, and that only after eighty stimuli.

Experiment 103

Experiment 103 was planned to find the effect on BR, if it was still present after attempted experimental extinction, of fifty *bell alone* with a shock following if the subject gives the conditional response.

R as a response to B was now punished whereas hitherto it had been rewarded to the extent that R to B prevented a shock when the apparatus was arranged to give S after B if the hand was not raised. The same stimulus bell was used as in the first experiment.* The results follow:

* The DPDT switch of the apparatus was thrown to the left. In this position of the switch, even though the experimenter depresses the shock key, the subject will not receive a shock as long as he does not raise his fingers from the lever. If he lifts them, the shock is given through the two mesh screens that are connected to his hand. These screens had been placed there at the beginning of the experiment.

A Go BR-S 2, BNR 1, BR-S 5, BNR 1, BR-S 1, BNR 2, BR-S 2, BNR 1, BR-S 1, BNR 25.*
M Bu BR-S 50.
L Ic BR-S 1, BNR 10.

When the conditional response was thus punished, it was elimininated in two out of the three subjects.

Experiment 104

Experiment 104 was performed to see the effect of increasing the shock substantially (presumably from 8 to 20 percent) for seven subjects who had responded with *No*; —; *No*; —; or its practical equivalent in Experiment 101 and who had not shown the conditional response. B was given along with *B and the stronger shock*, the occurrences being as previously in the ratio of 1 B to 4 BS. Their answers to questions 1 to 4 are given in Table 152.

The last fifty responses of the two subjects who reached the condition BSNR twenty times out of twenty are given below.

L Fa BNR 1, BSR 6, BNR 3, BSR 7, BR 2, BSNR 21, BNR 1, BSNR 5, BNR 2, BSNR 2.
W Sa BSR 4, BNR 1, BSNR 4, BSR 3, BSNR 16, BSR 2, BSNR 20.

The more usual effect of the increase of shock was to make these subjects avoid it by avoiding the experiment altogether, by means of complaints of pain.

An interpretation of the facts of Table 152 as a whole is that, if strength of shock has anything to do with the conditional response in humans, the probability is that the stronger the shock stimulus, the less like a purely reflex reaction the response becomes. The stronger shock is a greater temptation to raise the hand when its usual precursor is felt.

These results of a typical conditional reflex experiment show that the conditional response is not universally elicited from humans. The response occurred in but 8 percent of the cases. This result ought to be checked by trying to secure the conditional response from several hundred animals, setting up criteria for ending the experiment similar to the criteria in these experiments with humans.

* These records are read, taking A Go's for instance, as: bell followed rise of hand and shock twice in succession, bell no rise, once, bell rise and shock five times in succession, bell no rise, etc.

TABLE 152

THE RESPONSES OF THE SUBJECTS WHO ANSWERED AS SHOWN THE FOUR QUESTIONS AFTER EXPERIMENT 104, WITH RESULTING ACTION REGARDING THE RECORD

Subject	Shock in cm. of inductorium Day 1	Day 2	Responses	Action
L Fa	6.6	6.1	1. Yes 2. Once 3. No 4. — I believe the shock was stronger today than yesterday. The last part seemed weaker, as I became accustomed to it. No shock at all for the last two minutes	BSNR 20x20
W Sa	7.3	5.8	1. Never intentionally 2. I may have let it come up once or twice but I'm not sure 3. No 4. —	BSNR 20x20
C Me	6.5	6.0	1. — 2. — 3. — 4. — Sudden violent shocks which seemed much stronger than yesterday made me jump. It was the first onset which did it as far as I can see	Discarded—complaint of pain
M Ja	7.4	5.9	1. No 2. None 3. Yes 4. Whenever I discovered that the bell was not accompanied by a shock The effect of the current was quite painful. I acquired a fear of putting my hand on the brass and with a strong intention I made my hand stand. Even after putting my hand and without the ringing of the bell my hand was quivering. I was quite watchful. I let my hand stand until it is shocked. Sometimes, however, I used to discover that my hand had moved on the mere ringing of the bell without having received any shock, but simply in anticipating the shock	Discarded—complaint of pain
H Br	6.5	6.0	1. — 2. — 3. — 4. — Wondering when the electrical shock would cease and what was the increase of electricity. The shock forced me to lift my hand from the lever and my fingers ached very much from the shock	Discarded—complaint of pain
J Tu	7.0	5.6	1. No 2. — 3. Yes 4. At the beginning about five times	Discarded—complaint of pain
G Fo	7.4	5.9	1. Yes 2. I counted, since I was consciously drawn to attempt to avoid the "pain" to count the seconds before the shock was to come. I count approximately four seconds. Therefore I nervously withdrew my hand at about the fourth second. I did this about 10 percent of the total shocks given 3 Yes I also noticed that there were a series of "non-shock" ringings during which I consciously held my hand down. Sometimes I was in error. I consciously did this toward the end in about altogether 5 percent of the cases 4. —	Discarded

The development of the so-called conditional responses that were obtained differed from the reported course of the reaction in animals. The frequency of combined stimulation is greatly in excess of the frequency required to secure a stable response from animals.

In addition the course of experimental extinction differed materially from that of the reported cases of extinction. In all four subjects the response was not extinguished after 80 unreinforced stimulations and in three of the subjects not after 105 unreinforced stimulations.

It was shown that the defined minimal shock was probably not of such a nature as to be too weak to secure reaction, for when the shock was increased, five out of seven subjects complained of pain.

The facts obtained in this experiment seem more like those found in unconscious learning than like the formation of typical conditional responses. After-effects seemed to operate albeit without the awareness of the subject. The learning obtained is more like that in the experiments reported in Chapter X than that of the dog reacting with a scratch reflex to a bell.

In the case of those who came to respond to BS by NR, the after-effects of lifting the hand to avoid pain in *bell and shock* stimulation may have been so annoying and disturbing to the general situation of reading an interesting book, that, without awareness on the part of the subject, the response of not lifting the hand was selected. In the case of those who responded to B by R, there is the possibility that the pain of each shock was more disturbing than the lifting and that the lift response was selected in a similar manner without the subject's awareness of the selection.

The two responses BSNR and BR were not obtained suddenly. The tendency to make these responses developed for each subject during the course of the experiment. Trend lines have been splined to some of the data to discover whether or not suddenness is a fact. The conclusion is definite that whatever response was elicited from each subject, the responses developed gradually.

To enable those interested in the development of the particular responses to check the conclusions, the data for each subject used are appended. (Table 153.) The responses were classified for each successive twenty-five recordings as BSR BSNR BR and BNR.

TABLE 153

TYPES OF RESPONSES IN EACH SUCCESSIVE TWENTY-FIVE RECORDS FOR EACH INDIVIDUAL

Subject	Successive Twenty-Five Records in Order	Responses BSR	BSNR	BR	BNR	
M De	1	18	3	1	3	
	2	6	16	3	0	
	3	9	13	3	0	
	4	20	0	1	4	
	5	20	0	2	3	
	6	20	0	0	5	
	7	20	0	2	3	
	8	18	0	4	3	
	9	19	0	3	3	
	10	18	0	3	4	
	11	18	0	5	2	
	12	20	0	3	2	
	13	20	0	3	2	
	14	17	0	4	4	
	15	20	0	1	4	
	16	20	0	0	5	
	17*	18	0	5	1	
Total		301	32	43	48	= 424
J Mc	1	21	0	0	4	
	2	20	0	0	5	
	3	20	0	0	5	
	4	19	0	5	1	
	5	15	0	8	2	
	6	18	0	6	1	
	7	18	0	5	2	
	8	17	0	3	5	
	9	19	0	5	1	
	10	19	0	4	2	
	11	16	0	5	4	
	12	15	0	10	0	
	13	17	0	8	0	
	14	17	0	7	1	
	15	15	0	8	2	
	16	20	0	5	0	
	17	17	0	7	1	
	18	15	0	10	0	
	19	18	0	6	1	
	20	17	0	8	0	
	21	20	0	2	3	
	22	13	0	10	2	
	23	14	0	8	3	
	24	19	0	5	1	
	25	16	0	6	2	
	26	17	0	6	2	
	27	12	5	4	4	
	28	14	0	8	3	
	29	20	0	1	4	
	30	17	0	5	3	
	31	14	0	7	4	
	32	19	0	3	3	
	33	17	2	6	0	
	34	7	0	15	3	
	35*	2	0	1	6	
Total		574	7	108	86	= 850
B Go	1	20	0	0	5	
	2	19	0	0	6	
	3	20	0	0	5	
	4	21	0	0	4	
	5	20	0	0	5	
	6	20	0	0	5	
	7	21	0	1	3	
	8	21	0	0	4	
	9	20	0	1	4	
	10	19	0	0	6	
	11	12	8	1	4	
	12	18	2	0	5	
	13	15	5	0	5	
	14	20	0	0	5	
	15	21	0	0	4	
	16	20	0	0	5	
	17	21	0	2	2	
	18	19	0	1	5	
	19	20	0	0	5	
	20	20	0	0	5	
	21	20	0	0	5	
	22	20	1	0	4	
	23	14	6	1	4	
	24	20	1	0	4	
	25	18	2	0	5	
	26	11	10	0	4	
	27	18	0	5	2	
	28	7	0	15	3	
	29*	2	0	1	6	
Total		517	35	28	120	= 709
W L Ca	1	15	6	0	4	
	2	15	4	5	1	

* Asterisk means that there are less than 25 cases in the group.

TABLE 153 (*Continued*)

Subject	Successive Twenty-Five Records in Order	BSR	BSNR	BR	BNR
	3	15	4	6	0
	4	18	0	4	3
	5	17	0	7	1
	6	17	0	8	0
	7	10	0	15	0
	8	8	0	16	1
	9	9	0	16	0
	10	7	0	18	0
	11	7	0	17	1
	12	10	0	15	0
	13	13	0	10	2
	14	16	0	9	0
	15	8	0	16	1
	16	16	0	9	0
	17	17	0	8	0
	18	13	0	12	0
	19	15	0	10	0
	20	15	0	9	1
	21	21	0	4	0
	22	17	4	4	0
	23	12	4	7	2
	24	15	0	10	0
	25	14	6	3	2
	26	15	6	2	2
	27	15	4	5	1
	28	11	4	6	4
	29	10	0	13	2
	30	5	2	9	9
	31	11	8	3	3
	32	7	5	8	5
	33*	0	0	1	2
Total		414	57	275	47 = 803
M Re	1	19	4	2	0
	2	18	0	3	4
	3	20	1	0	4
	4	16	3	1	5
	5	15	3	4	3
	6	16	4	4	1
	7	12	9	1	3
	8	11	6	5	3
	9	12	8	2	3
	10	5	12	6	2
	11	6	11	2	6
	12	4	16	2	3
	13	6	15	1	3

Subject	Successive Twenty-Five Records in Order	BSR	BSNR	BR	BNR
	14	9	11	1	4
	15	5	13	3	4
	16	5	15	2	3
	17	11	3	10	1
	18	7	11	4	3
	19	8	10	2	5
	20	6	13	3	3
	21	6	10	3	6
	22	7	14	3	1
	23	4	16	3	2
	24	8	2	9	6
	25	9	4	7	5
	26	10	6	6	3
	27*	1	0	0	0
Total		256	220	89	86 = 651
L Fa	1	21	0	3	1
	2	19	0	5	1
	3	20	0	2	3
	4	17	0	4	4
	5	20	0	2	3
	6	21	0	1	3
	7	18	0	4	3
	8	16	1	6	2
	9	19	0	2	4
	10	16	4	0	5
	11	14	5	0	6
	12	3	16	0	6
	13	10	10	2	3
	14	7	13	0	5
	15	8	15	0	2
	16	8	15	0	2
	17	4	18	1	2
	18	9	10	0	6
	19	4	17	0	4
	20	7	13	0	5
	21	9	14	0	2
	22	11	4	5	5
	23	20	1	1	3
	24	5	18	0	2
	25	16	5	0	4
	26	7	15	0	3
	27	13	8	1	3
	28*	10	10	0	5
Total		352	212	39	97 = 700

TABLE 153 (*Continued*)

Subject	Successive Twenty-Five Records in Order	Responses BSR	BSNR	BR	BNR	
R Bo	1	21	0	0	4	
	2	20	0	1	4	
	3	20	0	0	5	
	4	20	0	1	4	
	5	20	1	0	4	
	6	20	0	0	5	
	7	21	0	0	4	
	8	21	0	0	4	
	9	19	0	0	6	
	10	20	0	0	5	
	11	20	0	0	5	
	12	19	0	1	5	
	13	17	0	0	8	
	14	20	0	0	5	
	15	21	0	1	3	
	16	19	1	0	5	
	17	21	0	0	4	
	18	19	0	1	4	
	19	17	3	3	2	
	20	18	1	1	5	
	21	14	2	1	8	
	22	18	3	2	2	
	23	15	2	6	2	
	24	18	0	4	3	
	25	16	0	6	3	
	26	17	0	5	3	
	27	18	3	1	3	
	28	17	3	2	3	
	29	18	2	0	5	
	30	19	1	2	3	
	31	18	2	4	1	
	32	17	4	1	3	
	33	13	8	1	3	
	34	10	11	2	2	
	35	15	6	0	4	
	36	15	7	0	3	
	37	8	15	0	2	
	38	15	6	0	4	
	39	4	19	1	1	
	40	10	15	0	0	
	41	10	13	0	2	
	42	8	16	0	1	
	43	11	12	0	2	
	44	15	8	0	2	
	45	12	6	4	3	
	46	14	4	3	4	
	47	14	2	4	5	
	48	5	0	10	10	
	49	5	0	11	14	
	50	0	0	10	10	
	51	0	0	12	13	
Total		782	176	101	216	= 1275
F Cr	1	20	0	2	3	
	2	20	0	3	2	
	3	21	0	2	2	
	4	21	0	1	3	
	5	15	5	1	4	
	6	14	7	2	2	
	7	17	4	1	3	
	8	17	1	5	2	
	9	16	5	2	2	
	10	16	4	1	4	
	11	16	4	3	2	
	12	10	9	4	2	
	13	18	2	2	3	
	14	8	12	4	1	
	15	9	13	2	1	
	16	3	18	3	1	
	17*	1	21	0	2	
Total		242	105	38	39	= 424
C Mo	1	20	0	0	5	
	2	12	8	0	5	
	3	15	4	2	4	
	4	15	6	0	4	
	5	17	2	0	6	
	6	17	3	0	5	
	7	4	15	0	6	
	8*	0	19	0	0	
Total		100	57	2	35	= 194
R Ke	1	20	0	3	2	
	2	18	0	5	2	
	3	18	0	5	2	
	4	18	0	3	4	
	5	15	6	0	4	
	6	18	3	1	3	
	7	12	8	2	3	
	8	19	1	1	4	
	9	18	2	3	2	
	10	20	0	4	1	

TABLE 153 (*Continued*)[a]

Subject	Successive Twenty-Five Records in Order	BSR	BSNR	BR	BNR	
	11	20	0	1	4	
	12	19	0	2	4	
	13	20	0	3	2	
	14	18	1	0	6	
	15	21	0	4	0	
	16	20	1	4	0	
	17	5	17	3	0	
	18	7	16	0	2	
	19	4	19	0	2	
	20	0	25	0	0	
	21*	0	2	0	0	
Total		310	101	44	47	= 502
S As	1	21	0	0	4	
	2	21	0	0	4	
	3	19	0	1	5	
	4	20	0	0	5	
	5	19	0	0	6	
	6	21	0	1	3	
	7	21	0	3	1	
	8	20	0	2	3	
	9	21	0	1	3	
	10	20	0	2	3	
	11	20	0	0	5	
	12	19	0	0	6	
	13	20	0	0	5	
	14	19	0	3	3	
	15	20	0	0	5	
	16	22	0	1	2	
	17	20	0	0	5	
	18	20	0	0	5	
	19	19	0	0	6	
	20	22	0	0	3	
	21	20	0	1	4	
	22	19	0	1	5	
	23	19	1	1	4	
	24	11	12	0	2	
	25	2	23	0	0	
	26*	1	21	0	0	
Total		476	57	17	97	= 647
I L Jo	1	9	13	0	3	
	2	10	14	1	0	
	3*	0	20	0	0	
Total		19	47	1	3	= 70
H Wo	1	21	0	0	4	

Subject	Successive Twenty-Five Records in Order	BSR	BSNR	BR	BNR	
	2	19	0	2	4	
	3	20	0	3	2	
	4	20	0	2	3	
	5	16	1	5	3	
	6	18	2	2	3	
	7	18	1	3	3	
	8	12	11	1	1	
	9	13	8	1	3	
	10	14	5	3	3	
	11	12	8	2	3	
	12	10	10	2	3	
	13	11	11	2	1	
	14	6	16	1	2	
	15	13	5	3	4	
	16	10	11	1	3	
	17	11	9	0	5	
	18	18	2	0	5	
	19	3	20	0	2	
	20	5	18	0	2	
	21	7	15	1	2	
	22	3	20	0	2	
	23	1	24	0	0	
	24*	0	11	0	0	
Total		281	208	34	63	= 586
A B Ga	1	16	5	2	2	
	2	8	13	0	4	
	3	6	15	1	3	
	4	5	16	0	4	
	5	3	20	0	2	
	6*	0	24	0	0	
Total		38	93	3	15	= 149
M Ja	1	19	2	1	3	
	2	12	11	1	1	
	3	9	15	0	1	
	4	2	22	0	1	
	5	4	21	0	0	
	6	10	13	0	2	
	7	8	16	0	1	
	8	9	14	0	2	
	9	3	22	0	0	
	10	4	21	0	0	
	11	3	21	1	0	
	12	12	13	0	0	
	13	5	18	0	2	
	14	12	11	0	2	
	15	21	0	0	4	

TABLE 153 (*Continued*)

Subject	Successive Twenty-Five Records in Order	Responses BSR	BSNR	BR	BNR	
	16	11	12	1	1	
	17	7	18	0	0	
	18	4	21	0	0	
	19	2	23	0	0	
	20	1	24	0	0	
	21	2	22	0	1	
	22	2	23	0	0	
	23	10	15	0	0	
	24	3	22	0	0	
	25	5	20	0	0	
	26	3	20	1	1	
	27	12	12	1	0	
	28	2	23	0	0	
	29*	2	21	0	1	
Total		199	496	5	23	= 724
A Ba	1	15	7	0	3	
	2	12	7	0	6	
	3	3	22	0	0	
	4*	0	20	0	0	
Total		30	56	0	9	= 95
W Sa	1	19	1	0	5	
	2	20	1	0	4	
	3	18	2	0	5	
	4	19	1	0	5	
	5	9	15	0	1	
	6	8	16	0	1	
	7	5	20	0	0	
	8	9	16	0	0	
	9	16	7	0	2	
	10	17	4	0	4	
	11	2	22	0	1	
	12	7	17	0	1	
	13	3	21	0	1	
	14	6	19	0	0	
	15	2	23	0	0	
	16	8	17	0	0	
	17	1	23	0	1	
	18	0	25	0	0	
	19*	0	4	0	0	
Total		169	254	0	31	= 454
P Ca	1	14	7	2	2	
	2	16	4	1	4	
	3	15	5	2	3	
	4	16	4	2	3	
	5	8	10	3	4	
	6	13	7	3	2	

Subject	Successive Twenty-Five Records in Order	Responses BSR	BSNR	BR	BNR	
	7	12	7	5	1	
	8	19	1	2	3	
	9	13	6	2	4	
	10	8	12	3	2	
	11	9	12	2	2	
	12	0	25	0	0	
	13*	0	10	0	0	
Total		143	110	27	30	= 310
J Ri	1	14	9	1	1	
	2*	0	15	0	0	
Total		14	24	1	1	= 40
A Go	1	21	0	0	4	
	2	19	0	3	3	
	3	18	1	3	3	
	4	14	0	9	2	
	5	17	0	8	0	
	6	5	0	19	1	
	7	4	0	19	2	
	8	6	0	19	0	
	9	3	0	20	2	
	10*	0	0	1	0	
Total		107	1	101	17	= 226
M H Ja	1	21	0	2	2	
	2	11	9	1	4	
	3	1	21	0	3	
	4*	1	13	0	0	
Total		34	43	3	9	= 89
H Bo	1	21	0	0	4	
	2	21	0	0	4	
	3	16	7	0	2	
	4	7	16	0	2	
	5	13	8	0	4	
	6	19	0	3	3	
	7	20	0	1	4	
	8	13	6	1	5	
	9	9	11	0	5	
	10	20	0	3	2	
	11	22	1	2	0	
	12	19	1	2	3	
	13	13	7	2	3	
	14	10	9	1	5	
	15	11	11	0	3	
	16	10	10	3	2	
	17	3	20	1	1	
	18	3	20	0	2	

TABLE 153 (*Continued*)

Subject	Successive Twenty-Five Records in Order	BSR	BSNR	BR	BNR	
	19	7	15	2	1	
	20*	1	0	0	0	
Total		258	142	21	55	= 476
L H Ho	1	8	15	0	2	
	2	12	9	0	4	
	3	2	20	0	3	
	4	2	22	0	1	
	5	1	23	0	1	
	6*	0	19	0	0	
Total		25	108	0	11	= 144
J Tu	1	21	0	0	4	
	2	20	0	0	5	
	3	20	0	1	4	
	4	20	0	3	2	
	5	20	0	2	3	
	6	20	0	1	4	
	7	19	0	3	3	
	8	20	0	2	3	
	9	19	0	2	4	
	10	20	0	1	4	
	11	20	0	1	4	
	12	20	0	3	2	
	13	20	0	0	5	
	14	19	0	0	6	
	15	21	0	1	3	
	16	18	0	2	5	
	17	20	0	2	3	
	18	19	0	1	5	
	19	20	0	0	5	
	20	20	0	2	3	
	21	20	0	3	2	
	22	20	0	3	2	
	23	20	0	2	3	
	24	21	0	1	3	
	25	20	0	3	2	
	26	20	0	1	4	
	27	21	0	1	3	
	28	21	0	3	1	
	29	20	0	3	2	
	30	21	0	0	4	
	31	20	0	0	5	
	32	20	0	4	1	
	33	21	0	0	4	

Subject	Successive Twenty-Five Records in Order	BSR	BSNR	BR	BNR	
	34	19	0	1	5	
	35	20	0	1	4	
	36	19	1	1	4	
	37	18	3	0	4	
	38	19	0	3	3	
	39	20	1	0	4	
	40	16	4	0	5	
	41	17	4	1	3	
	42	21	0	1	3	
	43	20	0	0	5	
	44	15	6	0	4	
	45	18	3	0	4	
	46	8	13	2	2	
	47	20	2	0	3	
	48	19	0	1	5	
	49	19	0	1	5	
	50	20	0	3	2	
	51	20	0	4	1	
	52	19	0	3	3	
	53	19	0	5	1	
	54	20	2	0	3	
	55	18	1	1	5	
	56	20	0	0	5	
	57	20	1	0	4	
	58	17	2	0	6	
	59	11	9	0	5	
	60	2	23	0	0	
	61	17	4	0	4	
	62	12	12	0	1	
	63	8	16	0	1	
	64	6	18	0	1	
	65	19	4	0	2	
	66	12	10	0	3	
	67	7	13	0	5	
	68	9	13	0	3	
	69	2	22	0	1	
	70*	1	8	0	2	
Total		1228	195	79	234	=1736
E E Mo	1	16	4	2	3	
	2	18	2	1	4	
	3	15	6	0	4	
	4	11	8	1	5	
	5	9	11	1	4	
	6	4	19	0	2	
	7	6	11	4	4	

TABLE 153 (*Continued*)

Subject	Successive Twenty-Five Records in Order	Responses BSR	BSNR	BR	BNR	
	8	4	18	0	3	
	9	3	18	0	4	
	10	0	25	0	0	
	11*	0	3	0	0	
Total		86	125	9	33	= 253
M T Wh	1	21	0	0	4	
	2	19	0	0	6	
	3	20	0	0	5	
	4	20	0	0	5	
	5	21	0	0	4	
	6	20	0	0	5	
	7	20	0	0	5	
	8	19	0	0	6	
	9	20	0	0	5	
	10	21	0	0	4	
	11	20	0	3	2	
	12	18	0	5	2	
	13	18	1	3	3	
	14	20	0	1	4	
	15	22	0	0	3	
	16	21	1	0	3	
	17	15	5	0	5	
	18	19	1	0	5	
	19	20	0	0	5	
	20	20	0	0	5	
	21	20	0	0	5	
	22	21	0	0	4	
	23	19	0	0	6	
	24	20	1	0	4	
	25	16	4	0	5	
	26	15	5	0	5	
	27	20	0	0	5	
	28	21	0	0	4	
	29	20	1	1	3	
	30	19	2	0	4	
	31	15	5	0	5	
	32	16	4	0	5	
Total		616	30	13	141	= 800
C Me	1	16	3	3	3	
	2	14	9	2	0	
	3	13	7	2	3	
	4	21	0	3	1	
	5	16	3	1	5	
	6	17	4	0	4	
	7	7	12	0	6	

Subject	Successive Twenty-Five Records in Order	Responses BSR	BSNR	BR	BNR	
	8	13	5	2	5	
	9	16	4	0	5	
	10	12	10	0	3	
	11	16	4	0	5	
	12	12	11	0	2	
	13	9	9	2	5	
	14	18	2	2	3	
	15	16	0	7	2	
	16	17	1	4	3	
	17	16	3	4	2	
	18	14	3	5	3	
	19	15	1	7	2	
	20	18	1	4	2	
	21*	11	0	1	10	
Total		307	92	49	74	= 522
M Bu	1	21	0	1	3	
	2	19	1	1	4	
	3	19	0	1	5	
	4	17	2	1	5	
	5	19	0	2	4	
	6	17	0	4	4	
	7	20	0	2	3	
	8	17	0	3	5	
	9	20	0	0	5	
	10	18	0	3	4	
	11	20	0	1	4	
	12	16	0	6	3	
	13	18	0	3	4	
	14	18	0	3	4	
	15	14	0	6	5	
	16	18	0	2	5	
	17	18	0	7	0	
	18	20	0	5	0	
	19	8	0	16	1	
	20	5	0	19	1	
	21	5	0	20	0	
	22*	0	0	4	0	
Total		347	3	110	69	= 529
D Jiv	1	19	1	0	5	
	2	15	5	2	3	
	3	16	5	2	2	
	4	14	8	1	2	
	5	16	7	0	2	
	6	14	8	1	2	
	7	15	5	1	4	

TABLE 153 (*Concluded*)

Subject	Successive Twenty-Five Records in Order	Responses BSR	BSNR	BR	BNR
	8	16	1	8	0
	9	13	9	2	1
	10	8	11	5	1
	11	17	1	5	2
	12	16	6	3	0
	13	13	11	0	1
	14	9	8	8	0
	15	12	4	9	0
	16	9	5	10	1
	17	10	4	11	0
	18	14	2	6	3
	19	13	4	6	2
	20	8	4	11	2
	21	9	14	1	1
	22	11	12	1	1
	23	6	5	14	0
	24	5	1	19	0
	25	16	1	6	2
	26	5	0	19	1

Subject	Successive Twenty-Five Records in Order	Responses BSR	BSNR	BR	BNR
	27*	4	0	19	1
Total		323	142	170	39 = 674
M E He	1	17	0	7	1
	2	4	0	20	1
	3	15	0	8	2
	4	12	4	6	3
	5	1	24	0	0
	6*	0	6	0	0
Total		49	34	41	7 = 131
L Ic	1	19	0	4	2
	2	21	0	0	4
	3	19	0	2	4
	4	11	0	14	0
	5	5	0	20	0
	6	16	0	9	0
	7	3	0	13	9
	8*	5	0	9	2
Total		99	0	71	21 = 191

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